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(54) **PYRROLE COMPOUNDS AS GRANZYME B INHIBITORS**

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(51) Int. Cl.

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A61K 31/4192 (2006.01)

C07D 249/04 (2006.01)

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C07D 403/14 (2006.01)

(52) U.S. Cl.

CPC **C07D 403/14** (2013.01); **A61K 31/41** (2013.01); **A61K 31/4192** (2013.01); **C07D 249/04** (2013.01); **C07D 257/04** (2013.01)

(58) Field of Classification Search

CPC **A61K 31/41**; **A61K 31/4192**; **C07D 249/04**; **C07D 257/04**

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See application file for complete search history.

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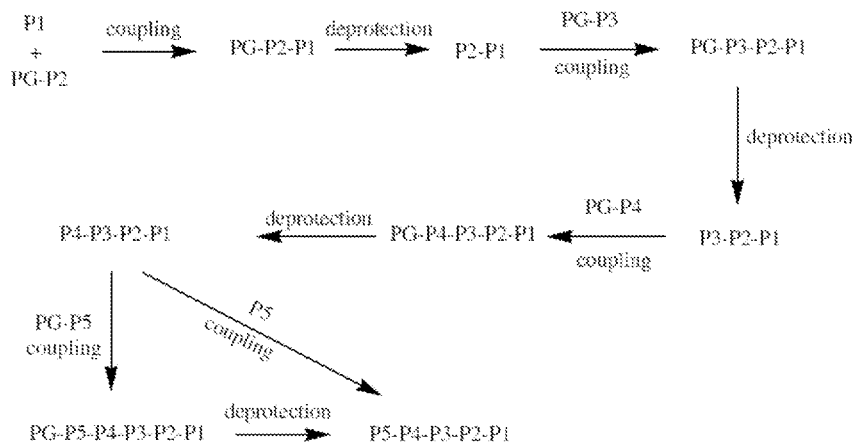
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(57) ABSTRACT

Pyrrole compounds as Granzyme B inhibitors, compositions that include the compounds, and methods for using the compounds. Method for treating cutaneous scleroderma, epidermolysis bullosa, radiation dermatitis, alopecia areata, and discoid lupus erythematosus are provided.

16 Claims, 3 Drawing Sheets



(56)

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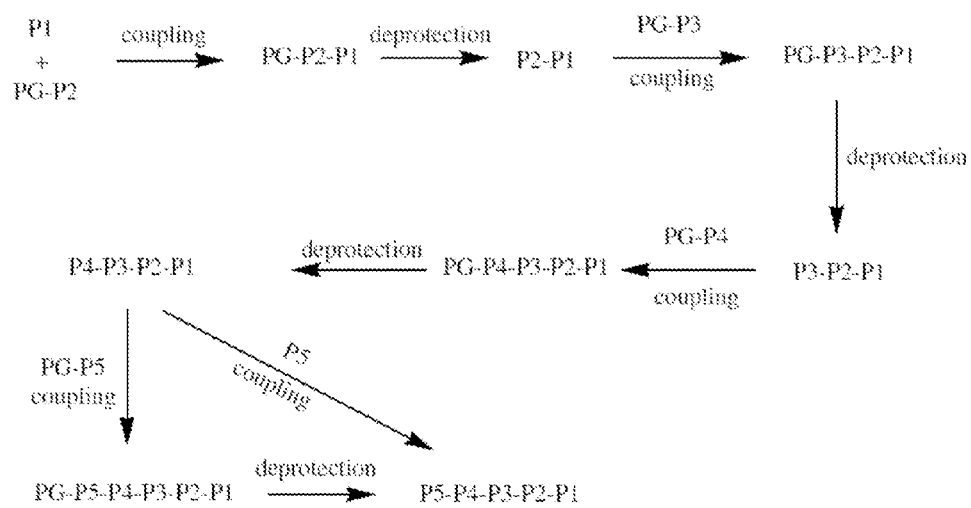
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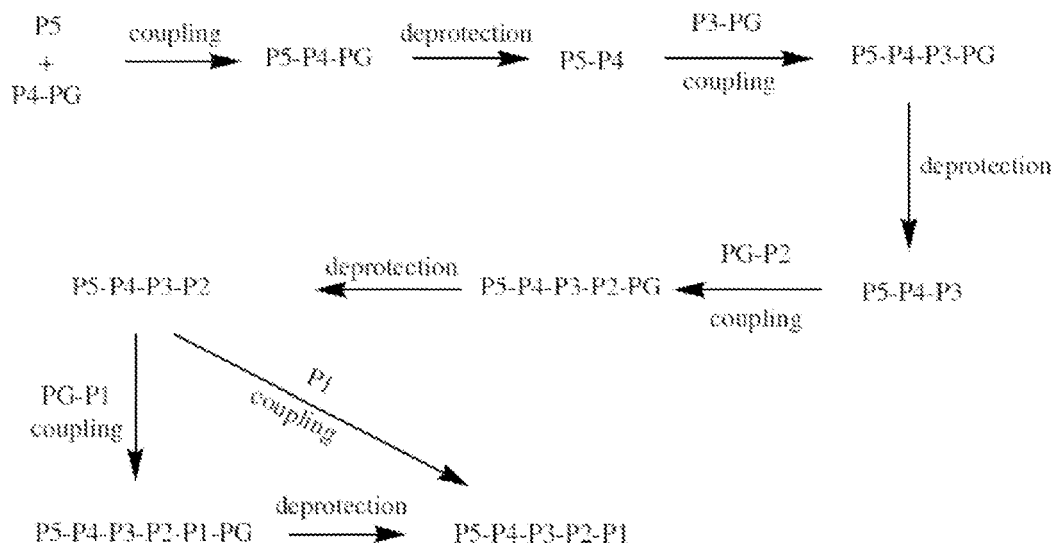
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**Fig. 1.**

**Fig. 2.**

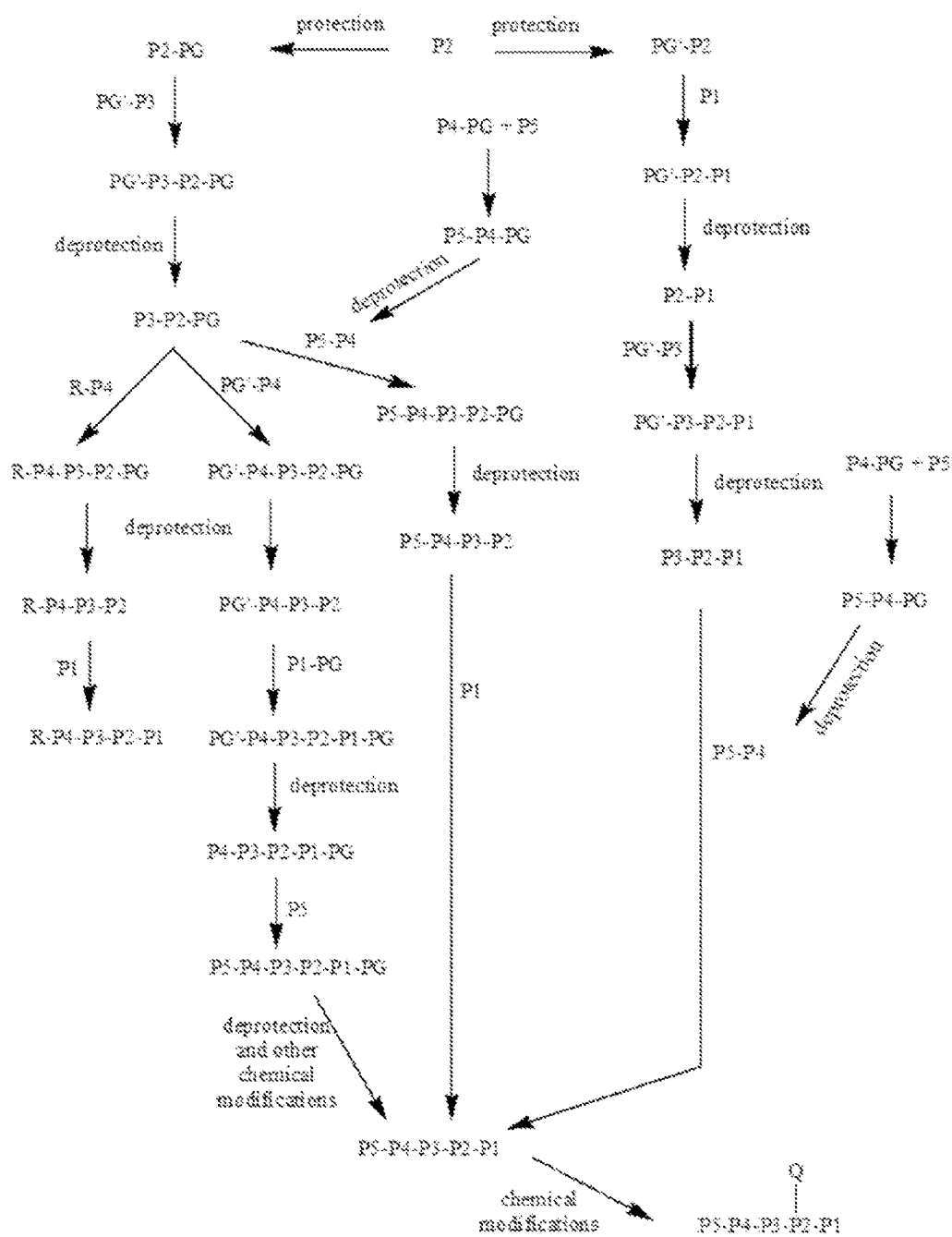


Fig. 3.

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PYRROLE COMPOUNDS AS GRANZYME B INHIBITORS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 62/032,454, filed Aug. 1, 2014, which application is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

Granzyme B is a pro-apoptotic serine protease found in the granules of cytotoxic lymphocytes (CTL) and natural killer (NK) cells. Granzyme B is released towards target cells, along with the pore-forming protein, perforin, resulting in its perforin-dependent internalization into the cytoplasm and subsequent induction of apoptosis (see, for e.g., Medema et al., *Eur. J. Immunol.* 27:3492-3498, 1997). However, during aging, inflammation and chronic disease, Granzyme B can also be expressed and secreted by other types of immune (e.g., mast cell, macrophage, neutrophil, and dendritic cells) or non-immune (keratinocyte, chondrocyte) cells and has been shown to possess extracellular matrix remodeling activity (Choy et al., *Arterioscler. Thromb. Vasc. Biol.* 24(12):2245-2250, 2004 and Buzza et al., *J. Biol. Chem.* 280:23549-23558, 2005).

Inhibitors of Granzyme B in humans have been limited to (a) relatively weak, nonspecific inhibitors such as isocoumarins (Otake et al., (1991), *Biochemistry*, 30(8), 2217-2227); (b) biological inhibitors such as serpinB9 (Sun et al., (1996), *J. Biol. Chem.*, 271(44), 27802-27809); (c) covalently coupled inhibitors such as aldehydes (Willoughby et al., (2002), *Bioorg. Med. Chem. Lett.*, 12(16), 2197), halomethyl ketones (Kam et al., (2000), *Biochim. Biophys. Acta*, 1477(1-2), 307-323), and phosphonates (Mahrus and Craik, (2005), *Chem. & Biol.*, 12, 567-77 and Kam et al., (2000)); and (d) tricyclic inhibitors (Willoughby et al., (2002)).

Nonspecific inhibitors (such as isocoumarins) are not sufficiently potent or specific to be effective treatments for Granzyme-B-related diseases, disorders, and conditions. Likewise, the use of biological inhibitors such as serpins is limited by the ability to deliver the inhibitor to the target mammal, the cost of manufacturing the biological agents, and other, off-target activities, such as inhibition of other serine proteases such as human neutrophil elastase (Dahlen et al., (1999), *Biochim. Biophys. Acta*, 1451(2-3), 233-41), Caspase-1 (Annaud et al., (1999), *Biochem. J.*, September 15; 342 Pt3, 655-65; Krieg et al., (2001), *Mol. Endocrinol.*, 15(11), 1971-82; and Young et al., (2000), *J. Exp. Med.*, 191(9), 1535-1544); Caspase-4 and Caspase-8 (Annaud et al., (1999)).

The tricyclic inhibitors (Willoughby et al. (2001)) also suffer from synthetic complexity/high manufacturing cost due to the complex core and accompanying low water solubility.

Despite the advances in development of Granzyme B inhibitors, there exists a need for compounds that inhibit Granzyme B with selectivity, that are relatively simple to manufacture at low cost, and that do not present drug delivery challenges. The present invention seeks to fulfill this need and provides further related advantages.

SUMMARY OF THE INVENTION

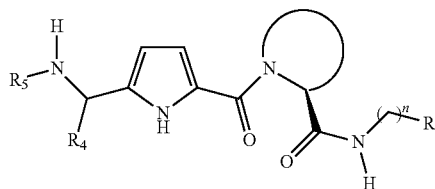
The present invention provides Granzyme B inhibitor compounds, compositions that include the compounds, and methods for using the compounds.

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In one aspect of the invention, the invention provides Granzyme B inhibitor compounds.

In one embodiment, the invention provides the compounds having Formula (I):

Formula (I)



its stereoisomers, tautomers, and pharmaceutically acceptable salts thereof, wherein:

R_1 is a heteroaryl group selected from

(a) 1,2,3-triazolyl, and

(b) 1,2,3,4-tetrazolyl;

n is 1 or 2;

R_4 is selected from

(i) C_1 - C_{12} alkyl,

(ii) C_1 - C_6 heteroalkyl optionally substituted with C_1 - C_6 alkyl,

(iii) C_3 - C_6 cycloalkyl,

(iv) C_6 - C_{10} aryl,

(v) heterocyclyl,

(vi) C_3 - C_{10} heteroaryl,

(vii) aralkyl, and

(viii) heteroalkylaryl;

R_5 is $-C(=O)-R_{10}$.

wherein R_{10} is selected from

(i) C_1 - C_{12} alkyl optionally substituted with C_6 - C_{10} aryl, C_1 - C_{10} heteroaryl, amino, or carboxylic acid,

(ii) C_1 - C_{10} heteroalkyl optionally substituted with C_1 - C_6 alkyl or carboxylic acid,

(iii) C_3 - C_6 cycloalkyl optionally substituted with C_1 - C_6 alkyl, optionally substituted C_6 - C_{10} aryl, optionally substituted C_3 - C_{10} heteroaryl, amino, or carboxylic acid,

(iv) C_6 - C_{10} aryl optionally substituted with C_1 - C_6 alkyl, optionally substituted C_6 - C_{10} aryl, optionally substituted C_3 - C_{10} heteroaryl, amino, or carboxylic acid,

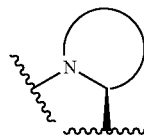
(v) heterocyclyl,

(vi) C_3 - C_{10} heteroaryl,

(vii) aralkyl, and

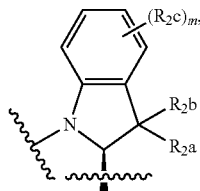
(viii) heteroalkylaryl;

Wherein



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is selected from



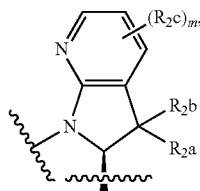
wherein

R_{2a} and R_{2b} are independently selected from hydrogen and C₁-C₃ alkyl, and

R_{2c} at each occurrence is independently selected from

- (a) hydrogen,
 (b) halogen,
 (c) C₁-C₆ alkyl,
 (d) —XR₁₁, wherein X is selected from O, C(=O), S, S=O, or S(=O)₂,
 (e) —C(=O)N(R₁₂)(R₁₃),
 (f) —N(R₁₁)(R₁₂)(R₁₃),
 (g) —N—C(=O)—R₁₁, and
 (h) —N—C(=O)O—R₁₁,

wherein R₁₁, R₁₂, and R₁₃ are independently selected from the group consisting of hydrogen, C₁-C₆ alkyl, C₁-C₆ heteroalkyl, C₂-C₆ alkenyl, C₆-C₁₀ aryl, aralkyl, and C₃-C₁₀ heteroaryl; and
 m is 1, 2, 3, or 4;



wherein

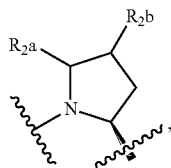
R_{2a} and R_{2b} are independently selected from hydrogen and C₁-C₆ alkyl; and

R_{2c} at each occurrence is independently selected from

- (a) hydrogen,
 (b) halogen,
 (c) C₁-C₆ alkyl,
 (d) —XR₁₁, wherein X is selected from O, C(=O), S, S=O, or S(=O)₂,
 (e) —C(=O)N(R₁₂)(R₁₃),
 (f) —N(R₁₁)(R₁₂)(R₁₃),
 (g) —N—C(=O)—R₁₁, and
 (h) —N—C(=O)O—R₁₁,

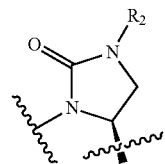
wherein R₁₁, R₁₂, and R₁₃ are independently selected from the group consisting of hydrogen, C₁-C₆ alkyl, C₁-C₆ heteroalkyl, C₂-C₆ alkenyl, C₆-C₁₀ aryl, aralkyl, and C₃-C₁₀ heteroaryl;

m is 1, 2, or 3;

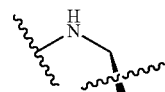


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wherein R_{2a} and R_{2b} are independently selected from hydrogen, C₁-C₆ alkyl, C₃-C₆ cycloalkyl, substituted and unsubstituted aryl, substituted and unsubstituted aralkyl, hydroxy, C₁-C₆ alkoxy, aryloxy, aralkoxy, alkylthio, arylthio, arylsulfonyl, arylsulfinyl, substituted and unsubstituted —O(C=O)-aryl, substituted and unsubstituted —O(C=O)-aralkyl, and substituted and unsubstituted —O(C=O)—C₁-C₆ alkyl;

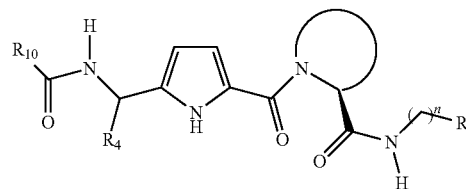


wherein R₂ is selected from hydrogen, C₁-C₆ alkyl, and C₃-C₆ cycloalkyl; and



In another embodiment, the invention provides compounds having Formula (II):

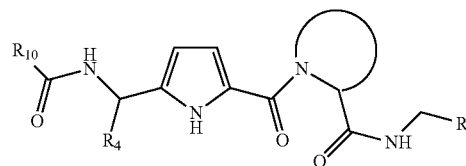
Formula (II)



its stereoisomers, tautomers, and pharmaceutically acceptable salts thereof, wherein R₁, R₄, R₁₀, and n are as above for Formula (I).

In a further embodiment, the invention provides compounds having Formula (III):

Formula (III)



its stereoisomers, tautomers, and pharmaceutically acceptable salts thereof, wherein R₁, R₄, and R₁₀ are as defined above for Formula (I).

In another aspect, the invention provides pharmaceutical compositions comprising a Granzyme B inhibitor compound of the invention and a pharmaceutically acceptable carrier.

In a further aspect of the invention, a method for inhibiting Granzyme B is provided. In one embodiment, the method comprises administering an effective amount of a

Granzyme B inhibitor compound of the invention or a pharmaceutical composition of the invention to a subject in need thereof.

In a further aspect of the invention, methods for treating a disease, disorder, or condition treatable by inhibiting Granzyme B is provided. In one embodiment, the method comprises administering a therapeutically effective amount of a Granzyme B inhibitor compound of the invention or a pharmaceutical composition of the invention to a subject in need thereof. Representative routes of administration include topical administration, oral administration, and administration by injection.

In one embodiment, the invention provides a method for treating discoid lupus erythematosus (DLE) comprising administering a therapeutically effective amount of a Granzyme B inhibitor compound of the invention or a pharmaceutical composition of the invention to a subject in need thereof. In certain embodiments, the Granzyme B inhibitor compound of the invention or pharmaceutical composition is administered topically.

Cosmetic compositions comprising a Granzyme B inhibitor compound of the invention and a cosmetically acceptable carrier are also provided, as are methods for using the compositions to treat, reduce, and/or inhibit the appearance of ageing in the skin.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a representative synthetic pathway for the preparation of representative compounds of the invention P5-P4-P3-P2-P1 starting from P1.

FIG. 2 is a schematic illustration of another representative synthetic pathway for the preparation of representative compounds of the invention P5-P4-P3-P2-P1 starting from P5.)

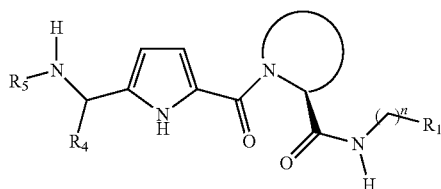
FIG. 3 is a schematic illustration of a further representative synthetic pathway for the preparation of representative compounds of the invention P5-P4-P3-P2-P1 starting from a component other than P1 or P5.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides Granzyme B inhibitor compounds, compositions that include the compounds, and methods for using the compounds. The compounds of the invention effectively inhibit Granzyme B.

In one aspect of the invention, the invention provides Granzyme B inhibitor compounds.

In one embodiment, the invention provides the compounds having Formula (I):



its stereoisomers, tautomers, and pharmaceutically acceptable salts thereof, wherein:

- R₁ is a heteroaryl group selected from
(a) 1,2,3-triazolyl, and
(b) 1,2,3,4-tetrazolyl;

n is 1 or 2;

R₄ is selected from

- (i) C₁-C₁₂ alkyl,
(ii) C₁-C₆ heteroalkyl optionally substituted with C₁-C₆ alkyl,

(iii) C₃-C₆ cycloalkyl,

(iv) C₆-C₁₀ aryl,

(v) heterocyclyl,

(vi) C₃-C₁₀ heteroaryl,

(vii) aralkyl, and

(viii) heteroalkylaryl;

R₅ is —C(=O)—R₁₀,

wherein R₁₀ is selected from

- (i) C₁-C₁₂ alkyl optionally substituted with C₆-C₁₀ aryl, C₁-C₁₀ heteroaryl, amino, or carboxylic acid,

- (ii) C₁-C₁₀ heteroalkyl optionally substituted with C₁-C₆ alkyl or carboxylic acid,

- (iii) C₃-C₆ cycloalkyl optionally substituted with C₁-C₆ alkyl, optionally substituted C₆-C₁₀ aryl, optionally substituted C₃-C₁₀ heteroaryl, amino, or carboxylic acid,

- (iv) C₆-C₁₀ aryl optionally substituted with C₁-C₆ alkyl, optionally substituted C₆-C₁₀ aryl, optionally substituted C₃-C₁₀ heteroaryl, amino, or carboxylic acid,

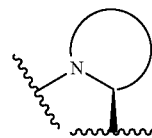
(v) heterocyclyl,

(vi) C₃-C₁₀ heteroaryl,

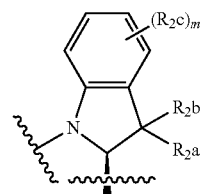
(vii) aralkyl, and

(viii) heteroalkylaryl;

wherein



is selected from



wherein

R_{2a} and R_{2b} are independently selected from hydrogen and C₁-C₆ alkyl; and

R_{2c} at each occurrence is independently selected from

(a) hydrogen,

(b) halogen,

(c) C₁-C₆ alkyl,

(d) —XR₁₁, wherein X is selected from O, C(=O), S, S=O, or S(=O)₂,

(e) —C(=O)N(R₁₂)(R₁₃),

(f) —N(R₁₁)(R₁₂)(R₁₃),

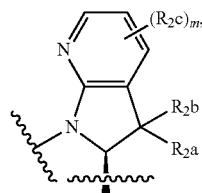
(g) —N—C(=O)—R₁₁, and

(h) —N—C(=O)O—R₁₁,

wherein R₁₁, R₁₂, and R₁₃ are independently selected from the group consisting of hydrogen, C₁-C₆ alkyl, C₁-C₆ heteroalkyl, C₂-C₆ alkenyl, C₆-C₁₀ aryl, aralkyl, and C₃-C₁₀ heteroaryl;

m is 1, 2, 3, or 4;

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wherein

R_{2a} and R_{2b} are independently selected from hydrogen and C1-C6 alkyl; and

R_{2c} at each occurrence is independently selected from

- (a) hydrogen,
- (b) halogen,
- (c) C₁-C₆ alkyl,
- (d) —XR₁₁, wherein X is selected from O, C(=O), S, S=O, or S(=O)₂,

(e) —C(=O)N(R₁₂)(R₁₃),

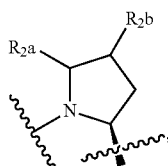
(f) —N(R₁₁)(R₁₂)(R₁₃),

(g) —N—C(=O)—R₁₁, and

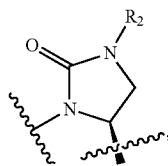
(h) —N—C(=O)O—R₁₁,

wherein R₁₁, R₁₂, and R₁₃ are independently selected from the group consisting of hydrogen, C₁-C₆ alkyl, C₁-C₆ heteroalkyl, C₂-C₆ alkenyl, C₆-C₁₀ aryl, aralkyl, and C₃-C₁₀ heteroaryl;

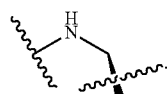
m is 1, 2, or 3;



wherein R_{2a} and R_{2b} are independently selected from hydrogen, C1-C6 alkyl, C3-C6 cycloalkyl, substituted and unsubstituted aryl, substituted and unsubstituted aralkyl, hydroxy, C1-C6 alkoxy, aryloxy, aralkoxy, alkylthio, arylthio, arylsulfonyl, arylsulfinyl, substituted and unsubstituted —O(C=O)-aryl, substituted and unsubstituted —O(C=O)-aralkyl, and substituted and unsubstituted —O(C=O)—C1-C6 alkyl;



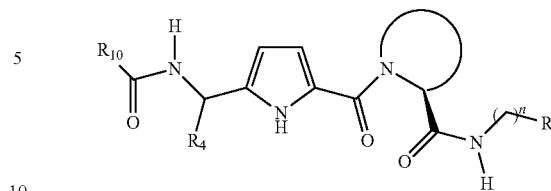
wherein R₂ is selected from hydrogen, C1-C6 alkyl, and C3-C6 cycloalkyl; and



In another embodiment, the invention provides compounds having Formula (II):

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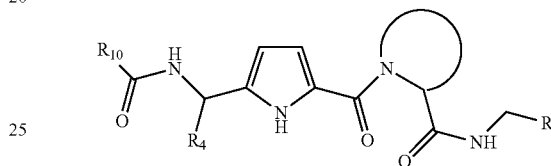
Formula (II)



its stereoisomers, tautomers, and pharmaceutically acceptable salts thereof, wherein R₁, R₄, R₁₀, and n are as above for Formula (I).

In a further embodiment, the invention provides compounds having Formula (III):

Formula (III)



its stereoisomers, tautomers, and pharmaceutically acceptable salts thereof, wherein R₁, R₄, and R₁₀ are as defined above for Formula (I).

In another embodiment, the invention provides compounds having Formulae (I), (II), or (III), wherein

R₁ is tetrazole or triazole;

R₄ is selected from

- (i) C₁-C₁₂ alkyl,
- (ii) C₃-C₆ cycloalkyl,
- (iii) C₆-C₁₀ aryl, and
- (iv) C₃-C₁₀ heteroaryl; and

R₅ is —C(=O)—R₁₀, wherein R₁₀ is selected from

- (i) C₁-C₁₂ alkyl optionally substituted with C₆-C₁₀ aryl, C₁-C₁₀ heteroaryl, amino, or carboxylic acid,
- (ii) C₁-C₁₀ heteroalkyl optionally substituted with C₁-C₆ alkyl or carboxylic acid,
- (iii) C₃-C₆ cycloalkyl optionally substituted with C₁-C₆ alkyl, optionally substituted C₆-C₁₀ aryl, optionally substituted C₃-C₁₀ heteroaryl, amino, or carboxylic acid,
- (iv) C₆-C₁₀ aryl optionally substituted with C₁-C₆ alkyl, optionally substituted C₆-C₁₀ aryl, optionally substituted C₃-C₁₀ heteroaryl, amino, or carboxylic acid, and (v) C₃-C₁₀ heteroaryl.

In certain embodiments, R₁₀, when defined as C₁-C₁₂ alkyl substituted with a carboxylic acid or carboxylate group, is:

—(CH₂)_n—CO₂H, where n is 2, 3, 4, 5, or 6;

optionally wherein one or more single methylene carbons are substituted with a fluoro, hydroxy, amino, C₁-C₃ alkyl (e.g., methyl), or C₆-C₁₀ aryl group;

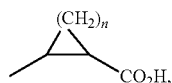
optionally wherein one or more single methylene carbons are substituted with two fluoro (e.g., difluoro, perfluoro) or C₁-C₃ alkyl (e.g., gem-dimethyl) groups;

optionally wherein one or more single methylene carbons are substituted with two alkyl groups that taken together with the carbon to which they are attached form a 3-, 4-, 5-, or 6-membered carbocyclic ring (e.g., spiro groups such as cyclopropyl, cyclobutyl, cyclopentyl, and cyclohexyl); and optionally wherein adjacent carbon atoms from an unsatu-

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rated carbon-carbon bond (e.g., alkenyl such as $-\text{CH}=\text{CH}-$) or taken from a benzene ring (e.g., 1,2-, 1,3-, and 1,4-phenylene); or

wherein R_{10} , when defined as $\text{C}_3\text{-C}_6$ cycloalkyl substituted with a carboxylic acid or carboxylate group, is:



wherein n is 1, 2, 3, or 4; and optionally, for $n=3$ or 4, wherein adjacent carbon atoms from an unsaturated carbon-carbon bond (e.g., cyclopentenyl or cyclohexenyl).

In certain embodiments, the invention provides compounds having Formulae (I), (II), or (III), its stereoisomers, tautomers, and pharmaceutically acceptable salts thereof, wherein:

R_1 is tetrazole or triazole;

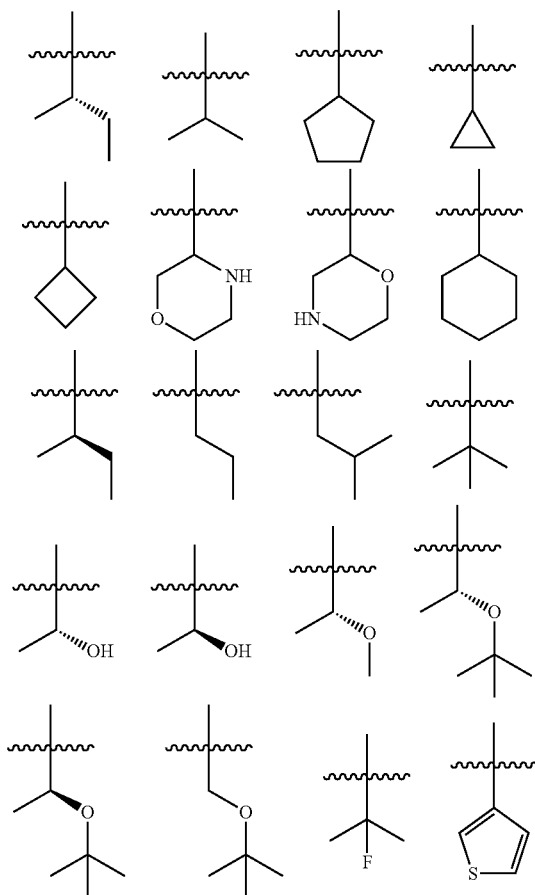
R_4 is $\text{C}_1\text{-C}_8$ alkyl or $\text{C}_3\text{-C}_6$ cycloalkyl; and

R_{10} is selected from

(a) $\text{C}_1\text{-C}_3$ alkyl substituted with $\text{C}_6\text{-C}_{10}$ aryl (e.g., phenyl) or $\text{C}_1\text{-C}_{10}$ heteroaryl (e.g., triazolyl or tetrazolyl); and

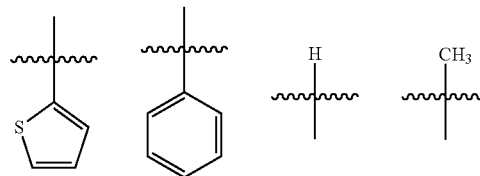
(b) $-(\text{CH}_2)_n\text{-CO}_2\text{H}$, where n is 2, 3, 4, 5, or 6.

For the compounds of Formulae (I), (II), or (III), representative substituents R_4 include the following:

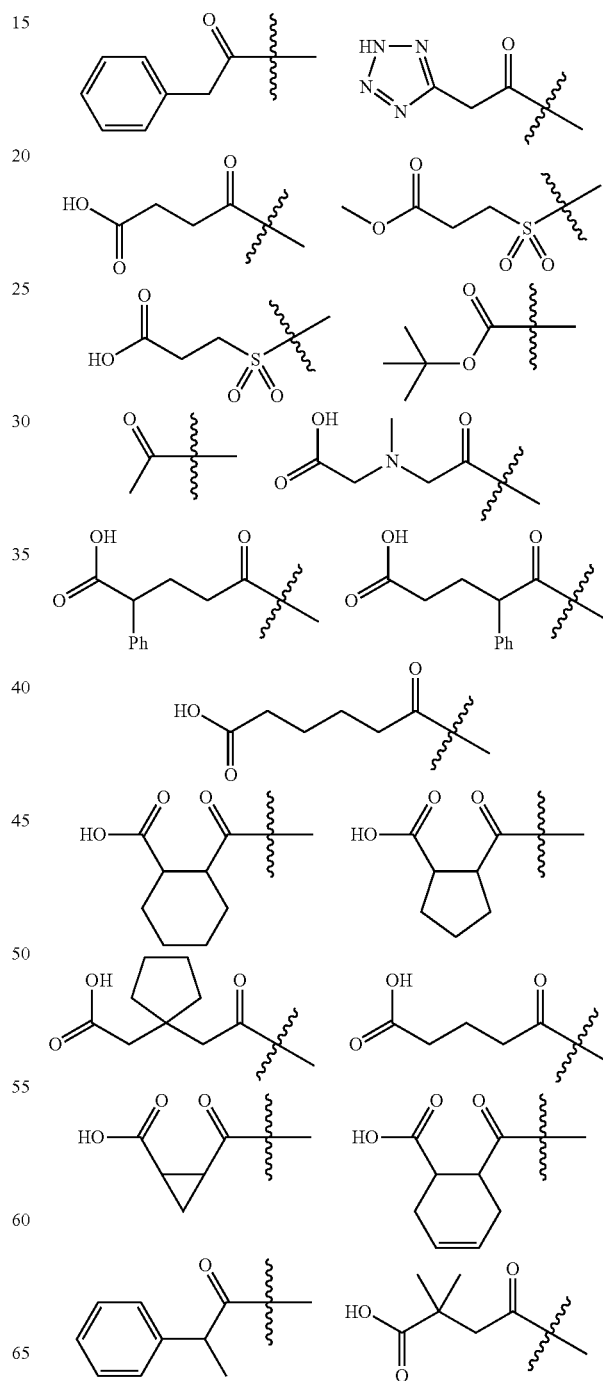


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-continued



For the compounds of Formulae (I), (II), or (III), representative substituents R_5 include the following:



-continued



-continued



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6

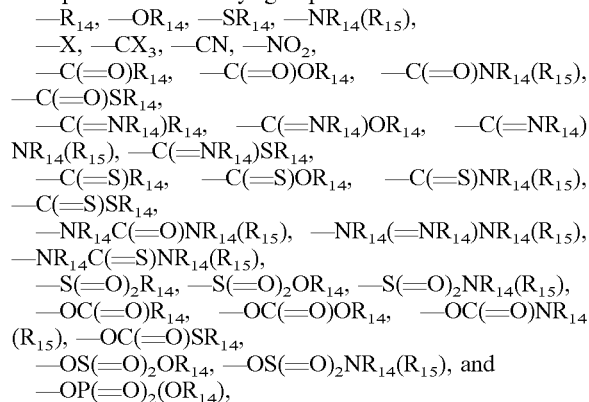
The invention is described using the following definitions unless otherwise indicated.

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As used herein, the term "alkyl" refers to a saturated or unsaturated, branched, straight-chain or cyclic monovalent hydrocarbon group derived by the removal of one hydrogen atom from a single carbon atom of a parent alkane, alkene, or alkyne. Representative alkyl groups include methyl; ethyls such as ethanyl, ethenyl, ethynyl; propyls such as propan-1-yl, propan-2-yl, cyclopropan-1-yl, prop-1-en-1-yl, prop-1-en-2-yl, prop-2-en-1-yl (allyl), cycloprop-1-en-1-yl; cycloprop-2-en-1-yl, prop-1-yn-1-yl, and prop-2-yn-1-yl; butyls such as butan-1-yl, butan-2-yl, 2-methyl-propan-1-yl, 2-methyl-propan-2-yl, cyclobutan-1-yl, but-1-en-1-yl, but-1-en-2-yl, 2-methyl-prop-1-en-1-yl, but-2-en-1-yl, but-2-en-2-yl, buta-1,3-dien-1-yl, buta-1,3-dien-2-yl, cyclobut-1-en-1-yl, cyclobut-1-en-3-yl, cyclobuta-1,3-dien-1-yl, but-1-yn-1-yl, but-1-yn-3-yl, and but-3-yn-1-yl; and the like. Where a specific level of saturation is intended, the expressions "alkanyl," "alkenyl," and "alkynyl" are used. Alkyl groups include cycloalkyl groups. The term "cycloalkyl" refers to mono-, bi-, and tricyclic alkyl groups having the indicated number of carbon atoms. Representative cycloalkyl groups include cyclopropyl, cyclopentyl, cycloheptyl, adamantyl, cyclododecylmethyl, and 2-ethyl-1-bicyclo[4.4.0]decyl groups. The alkyl group may be unsubstituted or substituted as described below.

"Alkanyl" refers to a saturated branched, straight-chain, or cyclic alkyl group. Representative alkanyl groups include methanyl; ethanyl; propanyls such as propan-1-yl, propan-2-yl(isopropyl), and cyclopropan-1-yl; butanyls such as butan-1-yl, butan-2-yl (sec-butyl), 2-methyl-propan-1-yl (isobutyl), 2-methyl-propan-2-yl(t-butyl), and cyclobutan-1-yl; and the like. The alkanyl group may be substituted or unsubstituted.

Representative alkanyl group substituents include



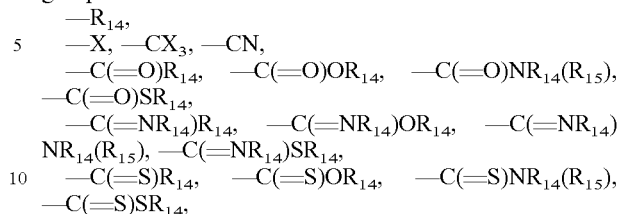
wherein each X is independently a halogen; and R_{14} and R_{15} are independently hydrogen, C1-C6 alkyl, C6-C14 aryl, arylalkyl, C3-C10 heteroaryl, and heteroarylalkyl, as defined herein.

In certain embodiments, two hydrogen atoms on a single carbon atom can be replaced with =O, =NR₁₂, or =S.

"Alkenyl" refers to an unsaturated branched, straight-chain, cyclic alkyl group, or combinations thereof having at least one carbon-carbon double bond derived by the removal of one hydrogen atom from a single carbon atom of a parent alkene. The group may be in either the cis or trans conformation about the double bond(s). Representative alkenyl groups include ethenyl; propenyls such as prop-1-en-1-yl, prop-1-en-2-yl, prop-2-en-1-yl (allyl), prop-2-en-2-yl, and cycloprop-1-en-1-yl; cycloprop-2-en-1-yl; butenyls such as but-1-en-1-yl, but-1-en-2-yl, 2-methyl-prop-1-en-1-yl, but-2-en-1-yl, but-2-en-2-yl, buta-1,3-dien-1-yl, buta-1,3-dien-2-yl, cyclobut-1-en-1-yl, cyclobut-1-en-3-yl,

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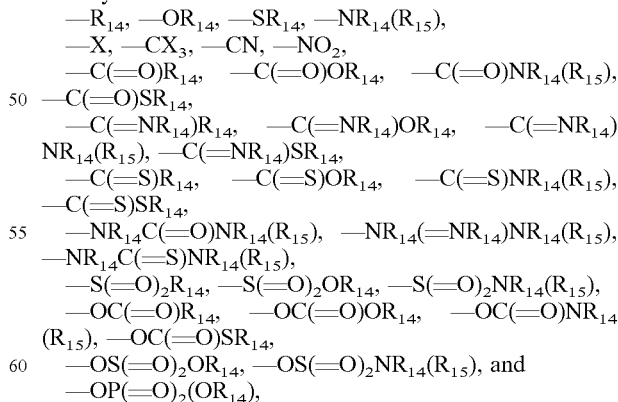
and cyclobuta-1,3-dien-1-yl; and the like. The alkenyl group may be substituted or unsubstituted. Representative alkenyl group substituents include



wherein each X is independently a halogen; and R_{14} and R_{15} are independently hydrogen, C1-C6 alkyl, C6-C14 aryl, arylalkyl, C3-C10 heteroaryl, and heteroarylalkyl, as defined herein.

"Alkynyl" refers to an unsaturated branched, straight-chain, or cyclic alkyl group having at least one carbon-carbon triple bond derived by the removal of one hydrogen atom from a single carbon atom of a parent alkyne. Representative alkynyl groups include ethynyl; propynyls such as prop-1-yn-1-yl and prop-2-yn-1-yl; butynyls such as but-1-yn-1-yl, but-1-yn-3-yl, and but-3-yn-1-yl; and the like. The alkynyl group may be substituted or unsubstituted. Representative alkynyl group substituents include those as described above for alkenyl groups.

The term "haloalkyl" refers to an alkyl group as defined above having the one or more hydrogen atoms replaced by a halogen atom. Representative haloalkyl groups include halomethyl groups such as chloromethyl, fluoromethyl, and trifluoromethyl groups; and haloethyl groups such as chloroethyl, fluoroethyl, and perfluoroethyl groups. The term "heteroalkyl" refers to an alkyl group having the indicated number of carbon atoms and where one or more of the carbon atoms is replaced with a heteroatom selected from O, N, or S. Where a specific level of saturation is intended, the expressions "heteroalkanyl," "heteroalkenyl," and "heteroalkynyl" are used. Representative heteroalkyl groups include ether, amine, and thioether groups. Heteroalkyl groups include heterocyclyl groups. The term "heterocyclyl" refers to a 5- to 10-membered non-aromatic mono- or bicyclic ring containing 1-4 heteroatoms selected from O, S, and N. Representative heterocyclyl groups include pyrrolidinyl, piperidinyl, piperazinyl, tetrahydrofuranlyl, tetrahydropuranyl, and morpholinyl groups. The heteroalkyl group may be substituted or unsubstituted. Representative heteroalkyl substituents include



wherein each X is independently a halogen; and R_{14} and R_{15} are independently hydrogen, C1-C6 alkyl, C6-C14 aryl, arylalkyl, C3-C10 heteroaryl, and heteroarylalkyl, as defined herein.

In certain embodiments, two hydrogen atoms on a single carbon atom can be replaced with =O, =NR₁₂, or =S.

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The term "alkoxy" refers to an alkyl group as described herein bonded to an oxygen atom. Representative C1-C3 alkoxy groups include methoxy, ethoxy, propoxy, and isopropoxy groups.

The term "alkylamino" refers an alkyl group as described herein bonded to a nitrogen atom. The term "alkylamino" includes monoalkyl- and dialkylaminos groups. Representative C1-C6 alkylamino groups include methylamino, dimethylamino, ethylamino, methylethylamino, diethylamino, propylamino, and isopropylamino groups.

The term "alkylthio" refers an alkyl group as described herein bonded to a sulfur atom. Representative C1-C6 alkylthio groups include methylthio, propylthio, and isopropylthio groups.

The term "aryl" refers to a monovalent aromatic hydrocarbon group derived by the removal of one hydrogen atom from a single carbon atom of a parent aromatic ring system. Suitable aryl groups include groups derived from acenaphthylene, acenaphthylene, acephenanthrylene, anthracene, azulene, benzene, chrysene, coronene, fluoranthene, fluorene, hexacene, hexaphene, hexalene, as-indacene, s-indacene, indane, indene, naphthalene, octacene, octaphene, octalene, ovalene, penta-2,4-diene, pentacene, pentalene, pentaphene, perylene, phenalene, phenanthrene, picene, pleiadene, pyrene, pyranthrene, rubicene, triphenylene, trinaphthalene, and the like. In certain embodiments, the aryl group is a C5-C14 aryl group. In other embodiments, the aryl group is a C5-C10 aryl group. The number of carbon atoms specified refers to the number of carbon atoms in the aromatic ring system. Representative aryl groups are phenyl, naphthyl, and cyclopentadienyl. The aryl group may be substituted or unsubstituted. Representative aryl group substituents include

—R₁₄, —OR₁₄, —SR₁₄, —NR₁₄(R₁₅),
—X, —CX₃, —CN, —NO₂,
—C(=O)R₁₄, —C(=O)OR₁₄, —C(=O)NR₁₄(R₁₅),
—C(=O)SR₁₄,
—C(=NR₁₄)R₁₄, —C(=NR₁₄)OR₁₄, —C(=NR₁₄)NR₁₄(R₁₅), —C(=NR₁₄)SR₁₄,
—C(=S)R₁₄, —C(=S)OR₁₄, —C(=S)NR₁₄(R₁₅),
—C(=S)SR₁₄,
—NR₁₄C(=O)NR₁₄(R₁₅), —NR₁₄(=NR₁₅)NR₁₄(R₁₅),
—NR₁₄C(=S)NR₁₄(R₁₅),
—S(=O)₂R₁₄, —S(=O)₂OR₁₄, —S(=O)₂NR₁₄(R₁₅),
—OC(=O)R₁₄, —OC(=O)OR₁₄, —OC(=O)NR₁₄(R₁₅), —OC(=O)SR₁₄,
—OS(=O)₂OR₁₄, —OS(=O)₂NR₁₄(R₁₅), and
—OP(=O)₂(OR₁₄),

wherein each X is independently a halogen; and R₁₄ and R₁₅ are independently hydrogen, C1-C6 alkyl, C6-C14 aryl, arylalkyl, C3-C10 heteroaryl, and heteroarylalkyl, as defined herein.

The term "aralkyl" refers to an alkyl group as defined herein with an aryl group, optionally substituted, as defined herein substituted for one of the alkyl group hydrogen atoms. Suitable aralkyl groups include benzyl, 2-phenylethan-1-yl, 2-phenylethan-1-yl, naphthylmethyl, 2-naphthylethan-1-yl, 2-naphthylethan-1-yl, naphthobenzyl, 2-naphthophenylethan-1-yl, and the like. Where specific alkyl moieties are intended, the terms aralkanyl, aralkenyl, and aralkynyl are used. In certain embodiments, the aralkyl group is a C6-C20 aralkyl group, (e.g., the alkanyl, alkenyl, or alkynyl moiety of the aralkyl group is a C1-C6 group and the aryl moiety is a C5-C14 group). In other embodiments, the aralkyl group is a C6-C13 aralkyl group (e.g., the alkanyl, alkenyl, or alkynyl moiety of the aralkyl group is a

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C1-C3 group and the aryl moiety is a C5-C10 aryl group. In certain embodiments, the aralkyl group is a benzyl group.

The term "heteroaryl" refers to a monovalent heteroaromatic group derived by the removal of one hydrogen atom from a single atom of a parent heteroaromatic ring system, which may be monocyclic or fused ring (i.e., rings that share an adjacent pair of atoms). A "heteroaromatic" group is a 5- to 14-membered aromatic mono- or bicyclic ring containing 1-4 heteroatoms selected from O, S, and N. Representative 5- or 6-membered aromatic monocyclic ring groups include pyridine, pyrimidine, pyridazine, furan, thiophene, thiazole, oxazole, and isooxazole. Representative 9- or 10-membered aromatic bicyclic ring groups include benzofuran, benzothiophene, indole, pyranopyrrole, benzopyran, quionoline, benzocyclohexyl, and naphthyridine. Suitable heteroaryl groups include groups derived from acridine, arindole, carbazole, β -carboline, chromane, chromene, cinnoline, furan, imidazole, indazole, indole, indoline, indolizine, isobenzofuran, isochromene, isoindole, isoindoline, isoquinoline, isothiazole, isoxazole, naphthyridine, oxadiazole, oxazole, perimidine, phenanthridine, phenanthroline, phenazine, phthalazine, pteridine, purine, pyran, pyrazine, pyrazole, pyridazine, pyridine, pyrimidine, pyrrole, pyrrolizine, quinazoline, quinoline, quinolizine, quinoxaline, tetrazole, thiadiazole, thiazole, thiophene, triazole, xanthene, and the like. In certain embodiments, the heteroaryl group is a 5-14 membered heteroaryl group. In other embodiments, the heteroaryl group is a 5-10 membered heteroaryl group. Preferred heteroaryl groups are those derived from thiophene, pyrrole, benzothiophene, benzofuran, indole, pyridine, quinoline, imidazole, oxazole, and pyrazine. The heteroaryl group may be substituted or unsubstituted. Representative heteroaryl group substituents include those described above for aryl groups.

The term "heteroarylalkyl" refers to an alkyl group as defined herein with a heteroaryl group, optionally substituted, as defined herein substituted for one of the alkyl group hydrogen atoms. Where specific alkyl moieties are intended, the terms heteroarylalkanyl, heteroarylalkenyl, or heteroarylalkynyl are used. In certain embodiments, the heteroarylalkyl group is a 6-20 membered heteroarylalkyl (e.g., the alkanyl, alkenyl or alkynyl moiety of the heteroarylalkyl is a C1-C6 group and the heteroaryl moiety is a 5-14-membered heteroaryl group). In other embodiments, the heteroarylalkyl group is a 6-13 membered heteroarylalkyl (e.g., the alkanyl, alkenyl or alkynyl moiety is C1-C3 group and the heteroaryl moiety is a 5-10-membered heteroaryl group).

The term "acyl" group refers to the —C(=O)—R' group, where R' is selected from optionally substituted alkyl, optionally substituted aryl, and optionally substituted heteroaryl, as defined herein.

The term "halogen" or "halo" refers to fluoro, chloro, bromo, and iodo groups.

The term "substituted" refers to a group in which one or more hydrogen atoms are each independently replaced with the same or different substituent(s).

Representative compounds of the invention and related intermediates were prepared from commercially available starting materials or starting materials prepared by conventional synthetic methodologies. Representative compounds of the invention were prepared according to Methods A to E as described below and illustrated in FIGS. 1-3. The preparations of certain intermediates (I-1 to I-10) useful in the preparation of compounds of the invention are described in the Synthetic Intermediate section below.

FIGS. 1-3 present schematic illustrations of representative synthetic pathways for the preparation of representative

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compounds of the invention P5-P4-P3-P2-P1. As used herein, "P5-P4-P3-P2-P1" refers to compounds of the invention prepared from five (5) components: P1, P2, P3, P4, and P5. Protected version of the components useful in the preparation of the compounds of the invention are designated as, for example, "PG-P2," "PG-P2-P1," "PG-P3," and "PG-P3-P2-P1," where "PG" is refers to a protecting group that allows for the coupling of, for example, P1 to P2 or P3 to P1-P2, and that is ultimately removed to provide, for example, P1-P2 or P1-P2-P3.

FIG. 1 is a schematic illustration of another representative synthetic pathway for the preparation of representative compounds of the invention P5-P4-P3-P2-P1 starting from P5. In this pathway, compound P5-P4-P3-P2-P1 is prepared in a stepwise manner starting with P5 by sequential coupling steps, separated as appropriate by deprotection steps and other chemical modifications. As shown in FIG. 1, P5 is coupled with PG-P4 to provide P5-P4-PG, which is then deprotected to provide P5-P4 and ready for coupling with the next component, P3-PG. The process is continued with subsequent couplings PG-P2 with P5-P4-P3 and PG-P1 with P5-P4-P3-P2 to ultimately provide P5-P4-P3-P2-P1.

FIG. 2 is a schematic illustration of a representative synthetic pathway for the preparation of representative com-

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pounds of the invention P5-P4-P3-P2-P1 starting from P1. In this pathway, compound P5-P4-P3-P2-P1 is prepared in a stepwise manner starting with P1 by sequential coupling steps, separated as appropriate by deprotection steps and other chemical modifications. As shown in FIG. 2, P1 is coupled with PG-P2 to provide PG-P2-P1, which is then deprotected to provide P2-P1 and ready for coupling with the next component, PG-P3. The process is continued with subsequent couplings PG-P4 with P3-P2-P1 and PG-P5 with P4-P3-P2-P1 to ultimately provide P5-P4-P3-P2-P1.

FIG. 3 is a schematic illustration of a further representative synthetic pathway for the preparation of representative compounds of the invention P5-P4-P3-P2-P1 starting from a component other than P1 or P5. In this pathway, compound P5-P4-P3-P2-P1 is prepared in a stepwise manner starting with P2 by sequential coupling steps, separated as appropriate by deprotection steps and other chemical modifications. As shown in FIG. 3, there are multiple pathways to P5-P4-P3-P2-P1. Examples C1-C9 were prepared by this method.

The preparation of representative compounds and their characterization are described in Examples C1-C9. The structures of representative compounds are set forth in Table 1.

TABLE 1

Representative Compounds.	
Cmpd #	Structure
C1-1	
C1-2	
C2	

TABLE 1-continued

Representative Compounds.	
Cmpd #	Structure
C3	 <chem>CC(C)[C@H](C(=O)NCC1=CN=CN1)C(=O)NCC2=CN=CN2</chem>
C4	 <chem>CC(C)[C@H](C(=O)NCC1=CN=CN1)C(=O)NCC2=CN=CN2</chem>
C5-1	 <chem>CC(C)[C@H](C(=O)NCC1=CN=CN1)C(=O)NCC2=CN=CN2</chem>
C5-2	 <chem>CC(C)[C@H](C(=O)NCC1=CN=CN1)C(=O)NCC2=CN=CN2</chem>
C6-1	 <chem>CC(C)[C@H](C(=O)NCC1=CN=CN1)C(=O)NCC2=CN=CN2</chem>
C6-2	 <chem>CC(C)[C@H](C(=O)NCC1=CN=CN1)C(=O)NCC2=CN=CN2</chem>

TABLE 1-continued

Representative Compounds.	
Cmpd #	Structure
C7-1	
C7-2	
C8-1	
C8-2	
C9	

A general kinetic enzyme assay useful for determining the inhibitory activity of the compounds of the invention is described in Examples D1 and D4.

A Granzyme B enzymatic inhibition assay is described in Example D2 and Example D5. The compounds of the

invention identified in Table 1 exhibited Granzyme B inhibitory activity. In certain embodiments, select compounds exhibited $IC_{50} < 50,000$ nM. In other embodiments, select compounds exhibited $IC_{50} < 10,000$ nM. In further embodiments, select compounds exhibited $IC_{50} < 1,000$ nM. In still

further embodiments, select compounds exhibited $IC_{50} < 100$ nM. In certain embodiments, select compounds exhibited IC_{50} from 10 nM to 100 nM, preferably from 1 nM to 10 nM, more preferably from 0.1 nM to 1 nM, and even more preferably from 0.01 nM to 0.1 nM.

A caspase enzymatic inhibition assay is described in Example D3 and Example D6. None of the compounds of the invention tested demonstrated an ability to significantly inhibit any of the caspases evaluated at a concentration of 50 μ M. In certain embodiments, the compounds exhibited less than 50% inhibition at 50 μ M. In other embodiments, the compounds exhibited greater than 50% inhibition at 50 μ M, but less than 10% inhibition at 25 μ M. The results demonstrate that select compounds of the invention selectively inhibit Granzyme B without significantly inhibiting caspases.

A cell detachment assay is described in Example D7.

A fibronectin cleavage assay is described in Example D8.

Pharmaceutical Compositions

The pharmaceutical compositions of the present invention include an inhibitor compound of the invention (e.g., a compound of Formulae (I), (II), or (III)) as an active ingredient or a pharmaceutically acceptable salt thereof in combination with a pharmaceutically acceptable carrier, and optionally other therapeutic ingredients.

The term "pharmaceutically acceptable salts" refers to salts prepared from pharmaceutically acceptable bases including inorganic bases and organic bases. Representative salts derived from inorganic bases include aluminum, ammonium, calcium, copper, ferric, ferrous, lithium, magnesium, manganic, manganous, ammonium, potassium, sodium, and zinc salts. Representative salts derived from pharmaceutically acceptable organic bases include salts of primary, secondary and tertiary amines, substituted amines including naturally occurring substituted amines, cyclic amines, and basic ion exchange resins, such as arginine, betaine, caffeine, choline, N,N'-dibenzylethylenediamine, diethylamine, 2-diethylaminoethanol, 2-dimethylaminoethanol, ethanolamine, ethylenediamine, N-ethyl-morpholine, N-ethylpiperidine, glucamine, glucosamine, histidine, hydrabamine, isopropylamine, lysine, methylglucamine, morpholine, piperazine, piperidine, polyamine resins, procaine, purines, theobromine, triethylamine, trimethylamine, tripropylamine, and trimethamine.

Compositions can include one or more carriers acceptable for the mode of administration of the preparation, be it by topical administration, lavage, epidermal administration, sub-epidermal administration, dermal administration, subdermal administration, transdermal administration, subcutaneous administration, systemic administration, injection, inhalation, oral, or any other mode suitable for the selected treatment. Topical administration includes administration to external body surfaces (e.g., skin) as well as to internal body surfaces (e.g., mucus membranes for vaginal or rectal applications by, for example, suppositories). Suitable carriers are those known in the art for use in such modes of administration.

Suitable compositions can be formulated by means known in the art and their mode of administration and dose determined by a person of skill in the art. For parenteral administration, the compound can be dissolved in sterile water or saline or a pharmaceutically acceptable vehicle used for administration of non-water soluble compounds. For enteral administration, the compound can be administered in a tablet, capsule, or dissolved or suspended in liquid form. The tablet or capsule can be enteric coated, or in a formulation for sustained release. Many suitable formulations are known

including, polymeric or protein microparticles encapsulating a compound to be released, ointments, pastes, gels, hydrogels, foams, creams, powders, lotions, oils, semi-solids, soaps, medicated soaps, shampoos, medicated shampoos, sprays, films, or solutions which can be used topically or locally to administer a compound. A sustained release patch or implant may be employed to provide release over a prolonged period of time. Many techniques known to one of skill in the art are described in Remington: the Science & Practice of Pharmacy by Alfonso Gennaro, 20th ed., Williams & Wilkins, (2000). Formulations can contain excipients, polyalkylene glycols such as polyethylene glycol, oils of vegetable origin, or hydrogenated naphthalenes. Biocompatible, biodegradable lactide polymer, lactide/glycolide copolymer, or polyoxyethylene-polyoxypropylene copolymers can be used to control the release of a compound. Other potentially useful delivery systems for a modulatory compound include ethylene-vinyl acetate copolymer particles, osmotic pumps, implantable infusion systems, and liposomes. Formulations can contain an excipient, for example, lactose, or may be aqueous solutions containing, for example, polyoxyethylene-9-lauryl ether, glycocholate, and deoxycholate, or can be an oily solution for administration in the form of drops, as a gel, or for other semi-solid formulation.

Compounds or pharmaceutical compositions in accordance with this invention or for use in the methods disclosed herein can be administered in combination with one or more other therapeutic agents as appropriate. Compounds or pharmaceutical compositions in accordance with this invention or for use in the methods disclosed herein can be administered by means of a medical device or appliance such as an implant, graft, prosthesis, stents, and wound dressings. Also, implants can be devised that are intended to contain and release such compounds or compositions. An example would be an implant made of a polymeric material adapted to release the compound over a period of time.

One skilled in the art will appreciate that suitable methods of administering a Granzyme B inhibitor directly to the eye are available (i.e., invasive and noninvasive methods). Although more than one route can be used to administer the Granzyme B inhibitor, a particular route can provide a more immediate and more effective reaction than another route. The present use is not dependent on the mode of administering the agent to an animal, preferably a human, to achieve the desired effect, and the described routes of administration are exemplary. As such, any route of administration is appropriate so long as the agent contacts an ocular cell. Thus, the Granzyme B inhibitor can be appropriately formulated and administered in the form of an injection, eye lotion, ointment, and implant.

The Granzyme B inhibitor can be applied, for example, systemically, topically, intracamerally, subconjunctivally, intraocularly, retrobulbarly, periorcularly (e.g., subtenon delivery), subretinally, or suprachoroidally. In certain cases, it can be appropriate to administer multiple applications and employ multiple routes to ensure sufficient exposure of ocular cells to the Granzyme B inhibitor (e.g., subretinal and intravitreal). Multiple applications of the Granzyme B inhibitor can also be required to achieve the desired effect.

Depending on the particular case, it may be desirable to non-invasively administer the Granzyme B inhibitor to a patient. For instance, if multiple surgeries have been performed, the patient displays low tolerance to anesthetic, or if other ocular-related disorders exist, topical administration of the Granzyme B inhibitor may be most appropriate. Topical formulations are well known to those of skill in the

art. Such formulations are suitable in the context of the use described herein for application to the skin or to the surface of the eye. The use of patches, corneal shields (see, U.S. Pat. No. 5,185,152), and ophthalmic solutions (see, e.g., U.S. Pat. No. 5,710,182) and ointments is within the skill in the art.

The Granzyme B inhibitor also can be present in or on a device that allows controlled or sustained release, such as an ocular sponge, meshwork, mechanical reservoir, or mechanical implant. Implants (see U.S. Pat. Nos. 5,443,505, 4,853,224 and 4,997,652), devices (see U.S. Pat. Nos. 5,554, 187, 4,863,457, 5,098,443 and 5,725,493), such as an implantable device (e.g., a mechanical reservoir, an intraocular device or an extraocular device with an intraocular conduit, or an implant or a device comprised of a polymeric composition are particularly useful for ocular administration of the expression vector). The Granzyme B inhibitor also can be administered in the form of sustained-release formulations (see U.S. Pat. No. 5,378,475) comprising, for example, gelatin, chondroitin sulfate, a polyphosphoester, such as bis-2-hydroxyethyl-terephthalate, or a polylactic-glycolic acid.

When used for treating an ocular disease the Granzyme B inhibitor is administered via an ophthalmologic instrument for delivery to a specific region of an eye. Use of a specialized ophthalmologic instrument ensures precise administration while minimizing damage to adjacent ocular tissue. Delivery of the Granzyme B inhibitor to a specific region of the eye also limits exposure of unaffected cells to the Granzyme B inhibitor. A preferred ophthalmologic instrument is a combination of forceps and subretinal needle or sharp bent cannula.

Alternatively, the Granzyme B inhibitor can be administered using invasive procedures, such as, for instance, intravitreal injection or subretinal injection, optionally preceded by a vitrectomy, or periocular (e.g., subtenon) delivery. The pharmaceutical composition of the invention can be injected into different compartments of the eye (e.g., the vitreal cavity or anterior chamber).

While intraocular injection is preferred, injectable compositions can also be administered intramuscularly, intravenously, intraarterially, and intraperitoneally. Pharmaceutically acceptable carriers for injectable compositions are well-known to those of ordinary skill in the art (see *Pharmaceutics and Pharmacy Practice*, J. B. Lippincott Co., Philadelphia, Pa., Banker and Chalmers, eds., pages 238-250 (1982), and *ASHP Handbook on Injectable Drugs*, Toissel, 4th ed., pages 622-630 (1986)).

An "effective amount" of a Granzyme B inhibitor or a pharmaceutical composition of the invention as described herein includes a therapeutically effective amount or a prophylactically effective amount. A "therapeutically effective amount" refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired therapeutic result, such as reduced levels of Granzyme B activity. A therapeutically effective amount of a compound may vary according to factors such as the disease state, age, sex, and weight of the subject, and the ability of the compound to elicit a desired response in the subject. Dosage regimens can be adjusted to provide the optimum therapeutic response. A therapeutically effective amount is also one in which any toxic or detrimental effects of the compound are outweighed by the therapeutically beneficial effects. A "prophylactically effective amount" refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired prophylactic result, such as Granzyme B activity. Typically, a prophylactic dose is used in subjects prior to or at an earlier

stage of disease, so that a prophylactically effective amount may be less than a therapeutically effective amount.

It is to be noted that dosage values can vary with the severity of the condition to be alleviated. For any particular subject, specific dosage regimens can be adjusted over time according to the individual need and the professional judgment of the person administering or supervising the administration of the compositions. Dosage ranges set forth herein are exemplary only and do not limit the dosage ranges that can be selected by a medical practitioner. The amount of active compound(s) in the composition can vary according to factors such as the disease state, age, sex, and weight of the subject. Dosage regimens can be adjusted to provide the optimum therapeutic response. For example, a single bolus can be administered, several divided doses can be administered over time or the dose can be proportionally reduced or increased as indicated by the exigencies of the therapeutic situation. It may be advantageous to formulate parenteral compositions in dosage unit form for ease of administration and uniformity of dosage.

In general, compounds of the invention should be used without causing substantial toxicity. Toxicity of the compounds of the invention can be determined using standard techniques, for example, by testing in cell cultures or experimental animals and determining the therapeutic index (i.e., the ratio between the LD₅₀, the dose lethal to 50% of the population, and the LD₁₀₀, the dose lethal to 100% of the population). In some circumstances however, such as in severe disease conditions, it may be necessary to administer substantial excesses of the composition.

Methods of Use

In a further aspect, the invention provides methods of using the compounds of the invention as Granzyme B inhibitors.

In one embodiment, the invention provides a method for inhibiting Granzyme B in a subject. In the method, an effective amount of a compound of the invention (e.g., a compound of Formulae (I), (II), or (III)) is administered to a subject in need thereof.

In another embodiment, the invention provides a method for treating a disease, disorder, or condition treatable by inhibiting Granzyme B. In the method, a therapeutically effective amount of a compound of the invention (e.g., a compound of Formulae (I), (II), or (III)) is administered to a subject in need thereof.

As used herein, the term "disease, disorder, or condition treatable by inhibiting Granzyme B" refers to a disease, disorder, or condition in which Granzyme B is involved in the pathway related to for the disease, disorder, or condition, and that inhibiting Granzyme B results in the treatment or prevention of the disease, disorder, or condition.

Representative methods of treatment using the compounds of the invention include those described for Granzyme B inhibitors in WO 2007/101354 (Methods of Treating, Reducing, and Inhibiting the Appearance of Ageing in the Skin), WO 2009/043170 (Treatment of Dissection, Aneurysm, and Atherosclerosis Using Granzyme B Inhibitors), WO 2012/076985 (Granzyme B Inhibitor Compositions, Methods and Uses for Promoting Wound Healing), each expressly incorporated herein by reference in its entirety. The compounds of the invention are useful for treating, reducing, and inhibiting the appearance of aging of the skin; treating dissection, aneurysm, and atherosclerosis; and promoting wound healing.

Other disease and disorders described as treatable using the Granzyme B inhibitors are disclosed in WO 2003/065987 (Granzyme B Inhibitors), expressly incorporated

herein by reference in its entirety. Disease and disorders described as treatable by Granzyme B inhibitors in this reference include autoimmune or chronic inflammatory diseases, such as systemic lupus erythematosus, chronic rheumatoid arthritis, type I diabetes mellitus, inflammatory bowel disease, biliary cirrhosis, uveitis, multiple sclerosis, Crohn's disease, ulcerative colitis, bullous pemphigoid, sarcoidosis, psoriasis, autoimmune myositis, Wegener's granulomatosis, ichthyosis, Graves ophthalmopathy, asthma, scleroderma and Sjogren's syndrome. The Granzyme B inhibitors described in the reference are noted as more particularly useful to treat or prevent diseases or disorders including diseases or disorders resulting from transplantation of organs or tissue, graft-versus-host diseases brought about by transplantation, autoimmune syndromes including rheumatoid arthritis, systemic lupus erythematosus, Hashimoto's thyroiditis, multiple sclerosis, myasthenia gravis, type I diabetes, uveitis, posterior uveitis, allergic encephalomyelitis, glomerulonephritis, post-infectious autoimmune diseases including rheumatic fever and post-infectious glomerulonephritis, inflammatory and hyperproliferative skin diseases, psoriasis, atopic dermatitis, contact dermatitis, eczematous dermatitis, seborrheic dermatitis, lichen planus, pemphigus, bullous pemphigoid, epidermolysis bullosa, urticaria, angioedemas, vasculitis, erythema, cutaneous eosinophilia, lupus erythematosus, acne, alopecia areata, keratoconjunctivitis, vernal conjunctivitis, uveitis associated with Behcet's disease, keratitis, herpetic keratitis, conical cornea, dystrophia epithelialis corneae, corneal leukoma, ocular pemphigus, Mooren's ulcer, scleritis, Graves' ophthalmopathy, Vogt-Koyanagi-Harada syndrome, sarcoidosis, pollen allergies, reversible obstructive airway disease, bronchial asthma, allergic asthma, intrinsic asthma, extrinsic asthma, dust asthma, chronic or inveterate asthma, late asthma and airway hyper-responsiveness, bronchitis, gastric ulcers, vascular damage caused by ischemic diseases and thrombosis, ischemic bowel diseases, inflammatory bowel diseases, necrotizing enterocolitis, intestinal lesions associated with thermal burns, coeliac diseases, proctitis, eosinophilic gastroenteritis, mastocytosis, Crohn's disease, ulcerative colitis, migraine, rhinitis, eczema, interstitial nephritis, Goodpasture's syndrome, hemolytic-uremic syndrome, diabetic nephropathy, multiple myositis, Guillain-Barre syndrome, Meniere's disease, polyneuritis, multiple neuritis, mononeuritis, radiculopathy, hyperthyroidism, Basedow's disease, pure red cell aplasia, aplastic anemia, hypoplastic anemia, idiopathic thrombocytopenic purpura, autoimmune hemolytic anemia, agranulocytosis, pernicious anemia, megaloblastic anemia, anerythroplasia, osteoporosis, sarcoidosis, fibroid lung, idiopathic interstitial pneumonia, dermatomyositis, leukoderma vulgaris, ichthyosis vulgaris, photoallergic sensitivity, cutaneous T cell lymphoma, arteriosclerosis, atherosclerosis, aortitis syndrome, polyarteritis nodosa, myocarditis, scleroderma, Wegener's granuloma, Sjogren's syndrome, adiposis, eosinophilic fascitis, lesions of gingiva, periodontium, alveolar bone, substantia ossea dentis, glomerulonephritis, male pattern alopecia or alopecia senilis by preventing epilation or providing hair germination and/or promoting hair generation and hair growth, muscular dystrophy, pyoderma and Sezary's syndrome, Addison's disease, ischemia-reperfusion injury of organs which occurs upon preservation, transplantation or ischemic disease, endotoxin-shock, pseudomembranous colitis, colitis caused by drug or radiation, ischemic acute renal insufficiency, chronic renal insufficiency, toxinoses caused by lung-oxygen or drugs, lung cancer, pulmonary emphysema, cataracta, siderosis, retinitis pigmentosa, senile macular degeneration,

vitreal scarring, corneal alkali burn, dermatitis erythema multiforme, linear IgA bullous dermatitis and cement dermatitis, gingivitis, periodontitis, sepsis, pancreatitis, diseases caused by environmental pollution, aging, carcinogenesis, metastasis of carcinoma and hypobaropathy, disease caused by histamine or leukotriene-C4 release, Behcet's disease, autoimmune hepatitis, primary biliary cirrhosis, sclerosing cholangitis, partial liver resection, acute liver necrosis, necrosis caused by toxin, viral hepatitis, shock, or anoxia, B-virus hepatitis, non-A/non-B hepatitis, cirrhosis, alcoholic cirrhosis, hepatic failure, fulminant hepatic failure, late-onset hepatic failure, "acute-on-chronic" liver failure, augmentation of chemotherapeutic effect, cytomegalovirus infection, HCMV infection, AIDS, cancer, senile dementia, trauma, and chronic bacterial infection. To the extent that the diseases and disorders noted in the reference are treatable by the Granzyme B inhibitors described in the reference, the Granzyme B inhibitors of the present invention are also useful in treating and/or ameliorating a symptom associated with these diseases and conditions.

Elevated Granzyme B levels have been identified in cells and tissues from subjects suffering from a variety of diseases and conditions including Rasmussen encephalitis, amyotrophic lateral sclerosis (ALS), chronic inflammation, Stevens-Johnson syndrome (SJS), toxic epidermal necrolysis (TEN), Kawasaki disease, idiopathic pulmonary fibrosis, chronic obstructive pulmonary disease (COPD), coronary artery disease (CAD), transplant vascular disease (TVD), restenosis, acute respiratory distress syndrome (ARDS), chronic obstructive sialadenitis (associated with sialolithiasis), vitiligo, allergic contact dermatitis (ACD), atopic dermatitis (AD), pityriasis rosea (PR), rheumatoid arthritis (RA), osteoarthritis (OA), vasculitic neuropathy, sensory perineuritis, ischemic stroke, spinal cord injury, myasthenia gravis (MG), lymphocytic gastritis, autoimmune cholangitis (AIC), nodular regenerative hyperplasia (NRH) of the liver, achalasia, esophagitis, eosinophilic fasciitis, cryptorchidism, necrotizing lymphadenitis, Duchenne muscular dystrophy, facioscapulo humeral muscular dystrophy, and Higashi syndrome. Other diseases and conditions in which elevated Granzyme B levels have been identified include those described in WO 2009/043167 (Granzyme A and Granzyme B Diagnostics), expressly incorporated herein by reference in its entirety. The Granzyme B inhibitors of the invention may be useful for treating, alleviating or ameliorating a symptom of, diminishing the extent of, stabilizing, or ameliorating or palliating the diseases and conditions noted above in which elevated Granzyme B levels have been identified. A description of intracellular versus extracellular Granzyme B in immunity and disease is provided in Granville et al., *Laboratory Investigation*, 2009, 1-26, expressly incorporated herein by reference in its entirety. The reference provides a listing of conditions in which the pathogenic role of Granzyme B has been identified.

The compounds of the invention are useful in treating cutaneous scleroderma, epidermolysis bullosa, radiation dermatitis, alopecia areata, and discoidal lupus erythematosus.

Cutaneous Scleroderma.

Scleroderma refers to a heterogeneous group of autoimmune fibrosing disorders. Limited cutaneous systemic sclerosis (CREST syndrome or LcSSc) develop sclerosis of the skin distal to their elbows and knees and have facial involvement. Patients with diffuse cutaneous systemic sclerosis (DcSSc) develop proximal, in addition to distal, skin sclerosis. Both groups of patients are also at high risk of developing internal organ involvement. Patients with LcSSc

and DcSSc suffer from Raynaud's phenomenon (excessively reduced blood flow in response to cold or emotional stress, causing discoloration of the fingers, toes, and occasionally other areas believed to be the result of vasospasms that decrease blood supply to the respective regions) with high frequencies. Management of progressive skin involvement is dependent on additional comorbidities. In patients with skin involvement only, mycophenolate mofetil (Cellsept, immunomodulator) or methotrexate (T cell modulator) have been recommended.

Epidermolysis Bullosa.

Epidermolysis bullosa acquisita (EBA) is a chronic mucocutaneous autoimmune skin blistering disease. EBA patients can be classified into two major clinical subtypes: noninflammatory (classical or mechanobullous) and inflammatory EBA, which is characterized by cutaneous inflammation. In patients with inflammatory EBA, widespread vesiculobullous eruptions are observed, typically involving the trunk, central body, extremities, and skin folds. Usually the patients suffer from pruritus (rashes). Autoantibodies targeting type VII collagen (COLT) has been implicated in the pathogenesis. Therefore, EBA is a prototypical autoimmune disease with a well-characterized pathogenic relevance of autoantibody binding to the target antigen. EBA is a rare disease with an incidence of 0.2-0.5 new cases per million and per year. The current treatment of EBA relies on general immunosuppressive therapy, which does not lead to remission in all cases.

Radiation Dermatitis.

Radiation Dermatitis (acute skin reaction) ranges from a mild rash to severe ulceration. Approximately 85-90% of patients treated with radiation therapy will experience a moderate-to-severe skin reaction. Acute radiation-induced skin reactions often lead to itching and pain, delays in treatment, and diminished aesthetic appearance—and subsequently to a decrease in quality of life. Skin reactions related to radiation therapy usually manifest within 1-4 weeks of radiation start, persist for the duration of radiation therapy, and may require 2-4 weeks to heal after completion of therapy. The severity of the skin reaction ranges from mild erythema (red rash) and dry desquamation (itchy, peeling skin) to more severe moist desquamation (open wound) and ulceration. Treatments that have been assessed for the management of radiation-induced skin reactions include topical steroid creams, nonsteroidal creams, dressings, and herbal remedies. Only three trials have showed a significant difference: one in favor of a corticosteroid cream, one favoring a nonsteroidal cream, and one for a dressing. However, all three of these trials were small and had limitations, thus there is still an unmet medical need.

Late effects of radiation therapy, typically months to years post exposure, occur at doses greater than a single dose of 20-25 Gy or fractionated doses of 70 Gy or higher. The major underlying histopathological findings at the chronic stage include telangiectasia, dense dermal fibrosis (round fibrosis), sebaceous and sweat gland atrophy, loss of hair follicles, and with higher doses, increased melanin deposition or depigmentation and skin ulcers.

Ramipril was very effective in reducing the late effects of skin injury, whereas its mitigating effects on the acute and sub-acute injury were modest. However, the dose required to mitigate these late effects may be pharmacologically too high to be clinically relevant. More recently, it has been shown that significant mitigation of acute skin injury using an adeno-associated virus encoding the manganese SOD gene, when injected subcutaneously shortly after irradiation.

However, difficulties in delivery, application and cost limit the utility of this treatment strategy.

Alopecia Aerata.

Alopecia areata (AA) is a CD8+ T-cell dependent autoimmune disease of the hair follicle (HF) in which the collapse of HF immune privilege (IP) plays a key role. Mast cells (MCs) are crucial immunomodulatory cells implicated in the regulation of T cell-dependent immunity, IP, and hair growth. Many of these infiltrating immune cells express GzmB, suggesting it may be a key mediator in immune cell-mediated follicular attack. The peptide substance P was shown to increase the CD8+ cells expressing GzmB in the intrafollicular dermis, co-relating to a regression of follicles into the catagen stage of follicle growth cessation (Siebenhaar et al., *J Invest Dermatol*, 2007, 127: 1489-1497).

In mice fed a diet with excess vitamin A, AA was accelerated and GzmB expressing cells were found in excess surrounding hair follicles, including in the isthmus (the region of the follicle containing stem cells) (Duncan et al., *J Invest Dermatol* 2013, 133: 334-343). As GzmB is expressed in the immune cell infiltrate within and surrounding growing follicles, it may be a key protease involved in hair loss through autoimmunity, apoptosis and ECM degradation.

No drug is currently approved by the US FDA for the treatment of alopecia areata. A number of treatments have been found to be effective using the American College of Physician's criteria, for example, topical and oral corticosteroids and the sensitizing agents diphenylcyclopropenone and dinitrochlorobenzene. However, there is no cure for alopecia areata, nor is there any universally proven therapy that induces and sustains remission.

Discoid Lupus Erythematosus.

Granzyme B is a serine protease found in cytoplasmic granules of cytotoxic lymphocytes and natural killer cells that plays an important role in inducing apoptotic changes in target cells during granule exocytosis-induced cytotoxicity. When Granzyme B is secreted into the cytoplasm of a target cell through the pore formed by perforin, it triggers cytotoxic-induced cell death (Shah et al., *Cell Immunology* 2011, 269:16-21).

Lupus erythematosus (LE) is a chronic, autoimmune, multisystem disease that displays many diverse symptoms in which localized cutaneous LE (CLE) is on one end of the spectrum and severe systemic LE (SLE) on the other end. CLE is a disfiguring, chronic skin disease, with a significant impact on the patients' everyday life. CLE are further divided into four main subsets: Acute CLE (ACLE), subacute CLE (SCLE) and chronic CLE (CCLE), where classic discoid LE (DLE) is the most common form. There is also a drug-induced form of the disease. The disease often has a chronic and relapsing course that can be induced or aggravated by UV light. CLE patients display well-defined skin lesions, often in sun-exposed areas. Discoid LE is the most common subtype of CLE, 60-80% is localized above the neck and 20-40% is generalized (lesions both above and below the neck). 70-90% of the DLE patients suffer from photosensitivity and sun exposed areas such as the scalp, ears and cheeks, which are most commonly involved areas. The lesions start as erythematous maculae or papules with a scaly surface and then grow peripherally into larger discoid plaques that heal with atrophic scar and pigmentary changes. DLE often results in scarring and alopecia. Mutilation with tissue loss can be seen when the lesions affect the ears and tip of the nose. CLE can be managed but so far, not cured. Avoidance of trigger factors is of utmost importance, such as, cessation of smoking and avoidance of sun exposure. The

treatment is about the same for the different CLE subsets where first-line of treatment is sun-protection and local therapy with corticosteroids or calcineurin inhibitors. Antimalarial are the first choice of systemic treatment.

Strong co-expression of Granzyme B and the skin-homing molecule, cutaneous lymphocyte antigen (CLA) was found in lesional lymphocytes of patients with scarring localized chronic DLE and disseminated chronic DLE, which was enhanced compared with nonscarring subacute CLE and healthy controls (Wenzel et al., *British Journal of Dermatology* 2005, 153: 1011-1015). Wenzel et al. conclude that skin-homing cytotoxic Granzyme B-positive lymphocytes play an important role in the pathophysiology of scarring chronic DLE and that the potentially autoreactive cytotoxic lymphocytes targeting adnexal structures may lead to scarring lesions in chronic DLE.

Correlation between Granzyme B-positive lymphocytes and the presence of CLE was shown by Grassi (Grassi et al., *Clinical and Experimental Dermatology* 2009, 34:910-914). Granzyme B is an apoptosis immunological mediator that, once synthesized and free from activated cytotoxic lymphocytes, enters the target cell and starts apoptotic mechanisms involved at different levels in all apoptotic pathways. In CLE, apoptosis is characterized by the presence of colloid or Civatte bodies, which are evident in the epidermis and papillary dermis of CLE lesions, and since Granzyme B is mainly expressed in CLE lesions, Grassi et al. conclude that Granzyme B could play a role in the induction of apoptotic mechanisms in CLE.

The expression of Granzyme B and perforin was correlated with clinicopathological features in patients with DLE, where both Granzyme B and perforin were expressed in DLE, with absent expression in normal skin (Abdou et al., *Ultrastructural Pathology* 2013, Early Online 1-9). Abdou et al. concluded that cytotoxicity in dermal lymphocytic inflammation was due to expression of both Granzyme B and perforin.

Extracellular Granzymes B is also reported to play a role in DLE by Grassi et al. Further, UV light increases Granzyme B expression in keratinocytes as well as mast cells (Hernandez-Pigeon, *J. Biol. Chem.*, 2007, 282:8157-8164). As Granzymes B is in abundance at the dermal-epidermal junction (DEJ), where many key extracellular matrix substrates are present (for example, laminin, fibronectin, decorin), it follows that Granzymes B may also be damaging the DEJ, as is observed in DLE. Given its expression in adnexal structures, Granzyme B may also be contributing to alopecia, as reduced Granzymes B is associated with reduced hair loss in a murine model of skin aging. Similarly, reduced extracellular Granzyme B activity is associated with improved collagen organization and reduced scarring in the skin and aorta.

In view of the established connection between Granzyme B and DLE, by virtue of their ability to inhibit Granzyme B, the compounds of the invention are useful in methods for treating lupus erythematosus (LE) including severe systemic LE (SLE) and localized cutaneous LE (CLE) (e.g., acute CLE (ACLE), subacute CLE (SCLE), chronic CLE (CCLE) and the most common form classic discoid LE (DLE)). In one embodiment, the invention provides a method for treating DLE comprising administering a therapeutically effective amount of a compound of the invention to a subject suffering from DLE.

Administration.

In the above methods, the administration of the Granzyme B inhibitor can be a systemic administration, a local administration (e.g., administration to the site, an inflamed

microenvironment, an inflamed joint, an area of skin, a site of a myocardial infarct, an eye, a neovascularized tumor), or a topical administration to a site (e.g., a site of inflammation or a wound).

The term "subject" or "patient" is intended to include mammalian organisms. Examples of subjects or patients include humans and non-human mammals, e.g., nonhuman primates, dogs, cows, horses, pigs, sheep, goats, cats, mice, rabbits, rats, and transgenic non-human animals. In specific embodiments of the invention, the subject is a human.

The term "administering" includes any method of delivery of a Granzyme B inhibitor or a pharmaceutical composition comprising a Granzyme B inhibitor into a subject's system or to a particular region in or on a subject. In certain embodiments, a moiety is administered topically, intravenously, intramuscularly, subcutaneously, intradermally, intranasally, orally, transcutaneously, intrathecal, intravitreally, intracerebral, or mucosally.

As used herein, the term "applying" refers to administration of a Granzyme B inhibitor that includes spreading, covering (at least in part), or laying on of the inhibitor. For example, a Granzyme B inhibitor may be applied to an area of inflammation on a subject or applied to, for example the eye or an area of inflammation by spreading or covering the surface of the eye with an inhibitor, by injection, oral or nasal administration.

As used herein, the term "contacting" includes contacting a cell or a subject with a Granzyme B inhibitor. Contacting also includes incubating the Granzyme B inhibitor and the cell together in vitro (e.g., adding the inhibitor to cells in culture) as well as administering the inhibitor to a subject such that the inhibitor and cells or tissues of the subject are contacted in vivo.

As used herein, the terms "treating" or "treatment" refer to a beneficial or desired result including, but not limited to, alleviation or amelioration of one or more symptoms, diminishing the extent of a disorder, stabilized (i.e., not worsening) state of a disorder, amelioration or palliation of the disorder, whether detectable or undetectable. "Treatment" can also mean prolonging survival as compared to expected survival in the absence of treatment.

Cosmetic Compositions and Related Methods

In further aspects, the invention provides cosmetic compositions that include one or more granzyme B inhibitors of the invention and methods for using the compositions to treat, reduce, and/or inhibit the appearance of ageing of the skin.

This aspect of the invention is based, in part, on the observation that granzyme B expression is induced in keratinocytes and immune cells, such as mast cells in the skin during aging. When released by these cells, granzyme B cleaves extracellular matrix proteins such as decorin which can result in collagen disorganization. This invention is also based in part on the observation that granzyme B cleaves decorin, in addition to other extracellular matrix proteins, in the interstitial space surrounding cells.

Skin is comprised of three main layers: the epidermis, the dermis and subcutaneous layers. Each of these three layers has individual compositions. The functions and structures of these layers are known to a person of skill in the art. The epidermis is the outermost layer of skin and includes both living and dead cell layers. The dermis is the middle layer of skin and is comprised of arrangements of collagen fibers, which surround many specialized cells and structures. Hair follicles are found within the dermis, and produce the hair shaft which grows out through layers of the dermis and epidermis to become visible as hair. The lowermost layer of

the skin is the subcutaneous layer, often called the subdermis. The subcutaneous layer is comprised largely of fat and connective tissue and houses larger blood vessels and nerves. Collagen may be found in all layers of the skin, but is most prominently in the dermis layer.

A youthful appearance is achieved by not having at least one of the characteristic signs of age. This is often achieved by being young. Nevertheless, there are circumstances in which being young does not confer a youthful appearance as a disease or disorder or other non-time related event has conferred the characteristics associated with age. A youthful appearance is often characterized by the condition of the skin and the following skin qualities are typically associated with, but not limited to, a youthful appearance: small pore size, healthy skin tone, radiance, clarity, tautness, firmness, plumpness, suppleness, elasticity, softness, healthy skin texture, healthy skin contours, such as few or no wrinkles, shallow wrinkle depth, few or no fine lines, healthy skin luster and brightness, moisturized skin, healthy skin thickness and resilient skin. If a skin of a subject comprises any one or more of these characteristics then a youthful appearance is achieved.

The appearance of ageing can occur for a variety of reasons, but typically happens at a normal rate associated with the passage of time. A rate of appearance of ageing will be different for different subjects, depending on a variety of factors including age, gender, diet and lifestyle. An appearance of ageing is often characterized by the condition of the skin. Characteristics associated with an appearance of ageing in the skin include, but are not limited to, skin fragility, skin atrophy, skin wrinkles, fine lines, skin discoloration, skin sagging, skin fatigue, skin stress, skin inelasticity, skin fragility, skin softening, skin flakiness, skin dryness, enlarged pore size, skin thinning, reduced rate of skin cell turnover, deep and deepening of skin wrinkles. The rate of appearance of ageing can be measured by measuring the rate at which any one or more of the above characteristics appear. An appearance of ageing may be inhibited, reduced, or treated by reducing or maintaining a state of any one or more of these skin characteristics.

In many circumstances a reduction in the appearance of ageing of skin occurs when the rate of collagen cleavage exceeds the rate of collagen formation. In many other circumstances, a youthful appearance of skin is maintained when the rate of collagen formation is equal to the rate of collagen cleavage. In many other circumstances, a reduction in a rate of appearance of ageing of skin is achieved when the rate of decorin cleavage and collagen disorganization and cleavage is slowed such that the rate of collagen fibrillogenesis exceeds the rate of collagen cleavage and the ratio of the rate of collagen fibrillogenesis to the rate of collagen cleavage is greater after application of granzyme B inhibitor compound compared to the ratio before application of the compound. In many other circumstances, an extracellular protein, other than decorin, is also cleaved by granzyme B, and the beneficial effects of inhibiting granzyme B can be enhanced beyond what is realized by inhibiting decorin cleavage alone.

In one aspect, the invention provides a cosmetic composition. The composition comprises a cosmetically acceptable carrier and one or more compounds of the invention (e.g., a compound of Formulae (I), (II), or (III), or stereoisomers, tautomers, and cosmetically acceptable salts thereof, as described herein).

As used herein, the term "cosmetically acceptable salt" refers to a salt prepared from a cosmetically acceptable base, such as an inorganic base and an organic base, or a salt

prepared from a cosmetically acceptable acid. Representative salts derived from inorganic bases include aluminum, ammonium, calcium, copper, ferric, ferrous, lithium, magnesium, manganic, manganous, ammonium, potassium, sodium, and zinc salts. Representative salts derived from cosmetically acceptable organic bases include salts of primary, secondary and tertiary amines, substituted amines including naturally occurring substituted amines, cyclic amines, and basic ion exchange resins, such as arginine, betaine, caffeine, choline, N,N'-dibenzylethylenediamine, diethylamine, 2-diethylaminoethanol, 2-dimethylaminoethanol, ethanolamine, ethylenediamine, N-ethyl-morpholine, N-ethylpiperidine, glucamine, glucosamine, histidine, hydrabamine, isopropylamine, lysine, methylglucamine, morpholine, piperazine, piperidine, polyamine resins, procaine, purines, theobromine, triethylamine, trimethylamine, tripropylamine, and trimethylamine.

The cosmetic compositions can be formulated by means known in the art and their mode of administration and the amount of granzyme B inhibitor compound as described herein can be determined by a person of skill in the art. Compositions for use in the methods described herein can comprise one or more of a granzyme B inhibitor compound or a cosmetically acceptable salt thereof as an active ingredient, in combination with a cosmetically acceptable carrier.

The cosmetic compositions can include diluents, excipients, solubilizing agents, emulsifying agents, and salts known to be useful for cosmetic compositions. Examples of suitable agents include thickeners, buffers, preservatives, surface active agents, neutral or cationic lipids, lipid complexes, liposomes, and penetration enhancers. In certain embodiments, the cosmetic compositions further include other cosmetic ingredients known in the art.

In certain embodiments, the cosmetic composition can include one or more penetration enhancers. Numerous types of penetration enhancers are known, such as fatty acids, bile salts, chelating agents, surfactants and non-surfactants (Lee et al., *Critical Reviews in Therapeutic Drug Carrier Systems* 8:91-192, 1991; Muranishi, *Critical Reviews in Therapeutic Drug Carrier Systems* 7:1-33, 1990). Fatty acids and their derivatives which act as penetration enhancers include, for example, caprylic acid, oleic acid, lauric acid, capric acid, caprylic acid, hexanoic acid, myristic acid, palmitic acid, valeric acid, stearic acid, linoleic acid, linolenic acid, arachidonic acid, oleic acid, elaidic acid, erucic acid, nervonic acid, dicaprate, tricaprate, recinleate, monoolein (also known as 1-monooleoyl-rac-glycerol), dilaurin, arachidonic acid, glyceryll-monocaprate, 1-dodecylazacycloheptan-2-one, acylcarnitines, acylcholines, mono- and di-glycerides and physiologically acceptable salts thereof (e.g., oleate, laurate, caprate, myristate, palmitate, stearate, linoleate) (Lee et al., *Critical Reviews in Therapeutic Drug Carrier Systems* page 92, 1991; Muranishi, *Critical Reviews in Therapeutic Drug Carrier Systems* 7:1, 1990; El-Hariri et al., *J. Pharm. Pharmacol.* 44:651-654, 1992).

In certain embodiments, the cosmetic composition further includes other cosmetic ingredients known in the art to be useful for cosmetic, skincare, and/or dermatological applications (e.g., anti-wrinkle active ingredients including flavone glycosides such as alpha-glycosylrutin; coenzyme Q10; vitamin E and derivatives; as well as sunblock ingredients, moisturizers, and perfumes).

The cosmetic compositions of the invention can be administered for "cosmetic" or "skincare" (e.g., dermatologic) applications, either alone or as an "additive" in combination with other suitable agents or ingredients. As used herein, "cosmetic" and "skincare" applications

includes, for example, preventive and/or restorative applications in connection with dermatological changes in the skin, such as, for example, during pre-mature skin aging; dryness; roughness; formation of dryness wrinkles; itching; reduced re-fatting (e.g., after washing); visible vascular dilations (e.g., telangiectases, couperosis); flaccidity; formation of wrinkles and lines; local hyperpigmentation; hypopigmentation; incorrect pigmentation (e.g., age spots); increased susceptibility to mechanical stress (e.g., cracking); skin-sagging (e.g., lack of firmness) and the appearance of dry or rough skin surface features.

The cosmetic compositions of the invention can be formulated for topical administration. Such compositions can be administered topically in any of a variety of forms. Such compositions are suitable in the context of the use described herein for application to the skin or to the surface of the eye. The use of patches, corneal shields (see, U.S. Pat. No. 5,185,152), and ophthalmic solutions (see, for example, U.S. Pat. No. 5,710,182) and ointments is within the skill in the art.

Compositions for topical administration include dermal patches, ointments, lotions, serums, creams, gels, hydrogels, pastes, foams, oils, semi-solids, shampoos, soaps, drops, sprays, films, liquids, and powders. Examples of such compositions include those in which a cosmetically effective amount of a compound of the invention is encapsulated in a vehicle selected from macro-capsules, micro-capsules, nano-capsules, liposomes, chylomicrons and microsponges. Another example of such a composition includes absorption of a compound of the invention on or to a material selected from powdered organic polymers, talcs, bentonites, and other mineral supports. A third example of such a composition or formulation includes a mixture of a cosmetically effective amount of a compound of the invention with other ingredients selected from extracted lipids, vegetable extracts, liposoluble active principles, hydrosoluble active principles, anhydrous gels, emulsifying polymers, tensioactive polymers, synthetic lipids, gelifying polymers, tissue extracts, marine extracts, vitamin A, vitamin C, vitamin D, vitamin E, solar filter compositions, and antioxidants. Other examples of suitable composition ingredients can be found in US2005/0249720.

In the cosmetic compositions, the compounds of the invention can be incorporated into any gelanic form, such as oil/water emulsions and water/oil emulsions, milks, lotions, gelifying and thickening tensioactive and emulsifying polymers, pomades, lotions, capillaries, shampoos, soaps, powders, sticks and pencils, sprays, and body oils.

Regardless of the compound or formulation described herein, application/administration to a subject as a colloidal dispersion system can be used as a delivery vehicle to enhance the in vivo stability of the compound and/or to target the granzyme B inhibitor compound to a particular skin layer, tissue or cell type. Colloidal dispersion systems include, but are not limited to, macromolecule complexes, nanocapsules, microspheres, beads and lipid-based systems including oil-in-water emulsions, micelles, mixed micelles, liposomes and lipid:inhibitor complexes of uncharacterized structure. An example of a colloidal dispersion system is a plurality of liposomes. Liposomes are microscopic spheres having an aqueous core surrounded by one or more outer layers made up of lipids arranged in a bilayer configuration (see, generally, Chonn et al., *Current Op. Biotech.* 6:698-708, 1995). Sustained-release dosage forms of the compounds described herein can also be used.

The amount of the granzyme B inhibitor compound administered or applied to a subject is not critical, except

that it should be an amount sufficient to effect improvement of the condition for which the composition is administered/applied. Application can be dependent on a number of factors, including severity and responsiveness of the condition to be treated, and with the course of treatment lasting from several days to several months, or until improvement of a condition is effected or a diminution of a symptom is achieved.

A "cosmetically effective amount" of a granzyme B inhibitor compound includes a cosmetically effective amount or a prophylactically effective amount. A "cosmetically effective amount" refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired cosmetic result, such as improved skin elasticity, skin durability, skin firming, skin texture, decrease the appearance or decrease rate of appearance of aging, and the like. A cosmetically effective amount of a compound may vary according to factors such as the skin state, age, sex, and weight of the subject, and the ability of the compound to elicit a desired response in the subject. Dosage regimens can be adjusted to provide the optimum cosmetic response. A cosmetically effective amount is also one in which any toxic or detrimental effects of the compound are outweighed by the cosmetically beneficial effects. A "prophylactically effective amount" refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired prophylactic result, such as improved skin elasticity, skin durability, skin firming, skin texture, a decrease appearance or a decrease in the rate of appearance of aging, and the like. Typically, a prophylactic dose is used in subjects prior to or at an earlier stage of skin deterioration, so that a prophylactically effective amount may be less than a cosmetically effective amount.

The amount of granzyme B inhibitor administered/applied may vary with the severity of the appearance, or rate of appearance, of age of the skin. For any particular subject, specific dosage regimens may be adjusted over time according to the individual need and the judgment of the person applying or supervising the applying of the compositions. Dosage ranges set forth herein are exemplary only and do not limit the dosage ranges that may be selected. The amount of granzyme B inhibitor compound(s) in the composition or formulation can vary according to factors such as the skin state, age, sex, and weight of the subject. Dosage regimens can be adjusted to provide the optimum response. For example, a single application can be administered/applied, several divided doses can be administered/applied over time or the amount of the composition administered/applied can be proportionally reduced or increased as indicated by the exigencies of the situation. It can be advantageous to formulate the granzyme B inhibitor compounds in a composition into a dosage unit form for ease of administration and uniformity of application.

By way of example, a granzyme B inhibitor compound of the cosmetic composition can be administered/applied to achieve from about 0.01 micrograms per milliliter ($\mu\text{g/mL}$) to about 10 milligrams per milliliter, from about 0.1 $\mu\text{g/mL}$ to about 500 $\mu\text{g/mL}$, from about 0.1 $\mu\text{g/mL}$ to about 1500 $\mu\text{g/mL}$, from about 1 $\mu\text{g/mL}$ to about 2000 $\mu\text{g/mL}$, and from about 0.1 $\mu\text{g/mL}$ to about 5000 $\mu\text{g/mL}$, including any range within these ranges, final concentrations at a target site.

Appropriate dosage values can depend on the characteristics of the site to which the composition is to be applied/administered and on the form of the granzyme B inhibitor compound used. Guidance as to particular dosages and methods of delivery is provided in the literature and generally available to practitioners in the art. Those skilled in the

art will employ different formulations for different uses and the granzyme B inhibitor compound used. Persons of ordinary skill in the art can easily estimate repetition rates for dosing based on measured residence times and concentrations of the granzyme B inhibitor compound in, for example, a bodily fluid or a tissue. Following successful treatment, it can be desirable to have the subject undergo maintenance therapy to prevent the recurrence of the condition, wherein a selected compound is administered/applied in maintenance doses applied, for example, once or more daily, to once every few days. In certain embodiments, granzyme B inhibitor compounds are administered/applied in an amount to achieve ex vivo concentrations from about 1 micromolar to about 10 millimolar, from about 10 micromolar to about 5000 micromolar, or from about 30 micromolar to about 3000 micromolar, and from about 25 micromolar to about 3000 micromolar final concentration over a site of interest, and including, about 25 micromolar, or about 1600 micromolar, or about 3000 micromolar final concentration over the site, and still more typically between about 1 micromolar to about 1000 micromolar.

Compounds or compositions of granzyme B inhibitors can be administered/applied by means of a device or appliance such as an implant, graft, prosthesis, garment of clothing, stent, and the like. Also, implants can be devised which are intended to contain and release such compounds or compositions. An example would be an implant made of a polymeric material adapted to release the compound over a period of time. Such implants can be placed into a garment to be worn by a subject, for example a glove, shirt, mask or hat.

The cosmetic compositions of the invention can be used to inhibit or reduce the appearance of ageing. Ageing is a natural phenomenon that cannot be reversed per se, but the appearance of ageing, such as skin deterioration including, but not limited to, skin inelasticity, skin fragility, skin softening, skin flakiness, skin dryness, enlarged pore size, skin thinning, reduced rate of skin cell turnover, skin wrinkling, deepening of skin wrinkles, skin sagging, fine lines, and skin discoloration may be inhibited or reduced.

The cosmetic compositions can be used to increase or decrease a rate of increasing or a rate of decreasing occurrences of a particular skin characteristic. In other words, the composition, when applied to the skin or a portion of the skin of a subject delays the onset of an appearance of aging. For example, in a population of subjects where half of the population applies a granzyme B inhibitor to their skin and another half of the population does not apply a granzyme B inhibitor to their skin, the half which applied a granzyme B inhibitor would not appear as aged as the half which did not apply the granzyme B inhibitor after a period of time had elapsed. The half of the population which applied a granzyme B inhibitor to the skin would also have maintained a youthful appearance.

The rate at which a particular subject experiences a change in the rate of appearance of a particular skin characteristic, i.e., an increasing or decreasing rate of the appearance of a particular skin characteristic, will depend on a variety of factors, including, but not limited to age, weight, sex and lifestyle of the subject. As such, rates are not necessarily constant, but a normal rate of increase or of decrease of an appearance of a characteristic, defined as being the new occurrence of a particular characteristic over a predetermined period of time under a set of conditions that do not include the presence of a granzyme B inhibitor applied by a method or use of this invention, is increased or decreased by applying a granzyme B inhibitor in accordance

with a method or use of this invention. Methods of measuring skin characteristics, rates of increasing appearance of skin characteristics and rates of decreasing appearance of skin characteristics are known to a person of skill in the art, see for example, *Measuring the Skin* by Agache et al., Springer (2004).

Surprisingly, granzyme B inhibitors can also be used to increase the density of hair follicles of a skin of a subject and may be used to reduce the occurrences of cutaneous xanthomas of a skin of a subject. Actively growing hair follicles contain melanocytes that transfer pigment to matrix keratinocytes, imparting color to hair. Additionally, sebum, produced in sebaceous glands, is often secreted via hair follicles. Increased density of hair follicles results in increased pigment production and increased sebum secretion resulting in improved hair appearance (e.g., hair that is less grey in color or not grey at all) as well as healthier hair and skin. Granzyme B inhibitors also cause hair follicles to appear deeper in the skin which provide stronger hair that is less susceptible to mechanical damage. Additionally, a characteristic sign of ageing is the reduction in hair follicle density. It is known in the art that age and follicular miniaturization are weak predictors of total hair count (see Chapman et al., *Brit. J. Dermatol.* 152:646-649, 2005). Consequently, the characteristic sign of age associated with hair follicle density is not predictive of hair density.

The cosmetic composition may be applied to a portion of the skin of a subject or to the whole of the skin of the subject. For example, the composition may be applied to the skin, only on the face, only on the scalp, on the whole head or to each part of the body.

INCORPORATION BY REFERENCE

Each reference cited is incorporated herein by reference in its entirety.

Abbreviations

As used herein, the following abbreviations have the indicated meanings.

¹H NMR: proton nuclear magnetic resonance

¹⁹F NMR: fluorine-19 nuclear magnetic resonance

% Inh: Percent inhibition

Ac-IEPD-AMC: acetyl-isoleucyl-glutamyl-prolyl-aspartyl-(7-amino-4-methylcoumarin) substrate

ACN: acetonitrile

BHET: bis-2-hydroxyethyl-terephthalate

Boc: tert-butoxycarbonyl

BSA: Bovine serum albumin

CHAPS: 3-[(3-cholamidopropyl)dimethylammonio]-1-propanesulfonate

DAPI: 4',6-diamidino-2-phenylindole

DCM: dichloromethane

DIPEA: diisopropylethylamine

DMAP: 4-dimethylaminopyridine

DMF: dimethylformamide

DMSO: dimethylsulfoxide

DMSO-d₆: dimethylsulfoxide-d₆

DTT: dithiothreitol

EDC: 1-(3-dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride

EDTA: 2-({2-[Bis(carboxymethyl)amino]ethyl})-(carboxymethyl)amino)acetic acid

ESI: Electrospray ionization

EtOAc: ethyl acetate

eq.: equivalent(s)

GzmB: Granzyme B

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HATU: 2-(7-aza-1H-benzotriazole-1-yl)-1,1,1,1-tetramethyluronium hexafluorophosphate

HCl: hydrochloric acid

HEPES: 4-(2-hydroxyethyl)-1-piperazineethanesulfonic acid

hGzmB: human Granzyme B

HPLC: high performance liquid chromatography

HOBt: 1-hydroxy-benzotriazol

IC₅₀: inhibitory concentration that provides 50% inhibition

LC/MS: liquid chromatography/mass spectrometry

MeOH: methanol

mGzmB: murine Granzyme B

MS: mass spectrometry

m/z: mass to charge ratio.

Oxyma: ethyl 2-cyano-2-(hydroxyimino)acetate

PBS: phosphate buffered saline (pH 7.4)

RPM: revolution per minute

RT: room temperature

tert-BuOH: tert-butyl alcohol

THF: tetrahydrofuran

TFA: trifluoroacetic acid

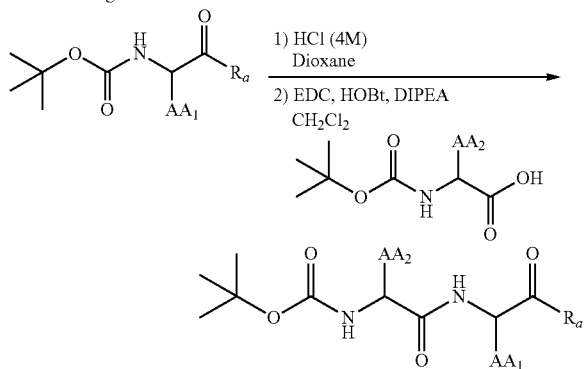
wt %: weight percent

General Methods A-E

Representative compounds of the invention were prepared according to Methods A to E as described below and illustrated in FIGS. 1-3.

It will be appreciated that in the following general methods and preparation of synthetic intermediates, reagent levels and relative amounts or reagents/intermediates can be changed to suit particular compounds to be synthesized, up or down by up to 50% without significant change in expected results.

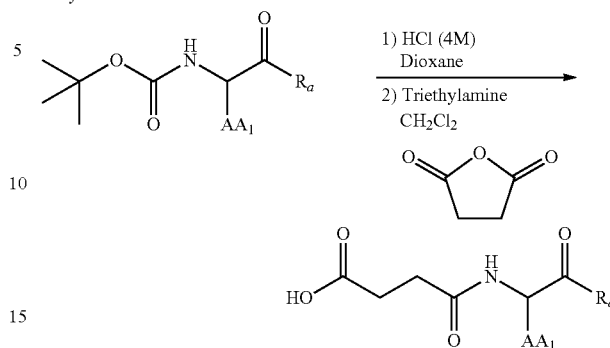
Method A: General method for deprotection followed by coupling reaction using EDC/HOBt/DIPEA.



HCl Solution in dioxane (4M, 5 ml) was added to respective carbamate compound (0.125 mmol) and stirred for 2 hrs at RT. The reaction mixture was concentrated to dryness under vacuum and swapped with MeOH (5 ml) three times. The resulting residue was dried well under vacuum and subjected to next reaction as it was. The residue obtained above, respective acid moiety (0.125 mmol), EDC (0.19 mmol), HOBt (0.16 mmol) and DIPEA (0.5 mmol) were stirred in anhydrous DCM (5 ml) for 16 hrs. The reaction mixture was concentrated under vacuum to give the crude product which was purified on a C18 column using 10-50% MeOH in water to yield product as an off-white solid (35-55%).

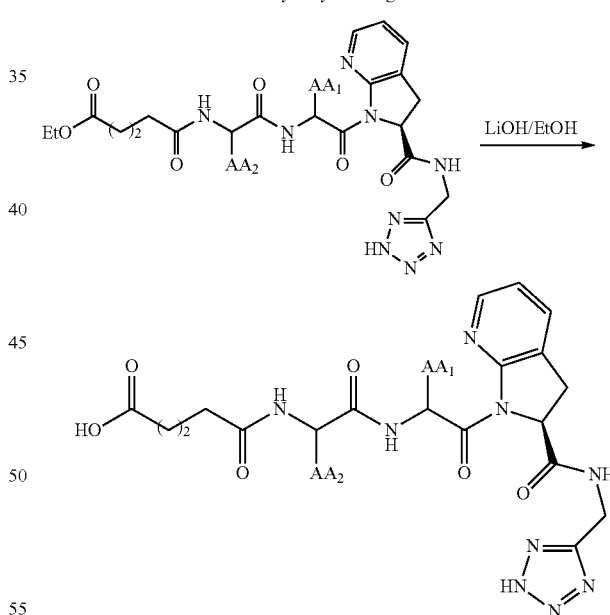
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Method B: General method for deprotection followed by reaction with anhydride.



HCl Solution in dioxane (4M, 5 ml) was added to a representative Boc-protected compound (0.125 mmol) and stirred for 2 hrs at RT. The reaction mixture was concentrated to dryness under vacuum and washed with MeOH (5 ml) three times. The resulting residue was dried well under vacuum and subjected to next reaction as it was. The residue obtained above, the respective anhydride moiety (0.125 mmol), and triethylamine (0.5 mmol) were added to anhydrous DCM (5 mL) and stirred for 16 hrs. The mixture was concentrated under vacuum to give the crude product which was purified on a C18 column using 10-50% MeOH in water to yield product as an off-white solid (40-60%).

Method C: General method of hydrolysis using LiOH.

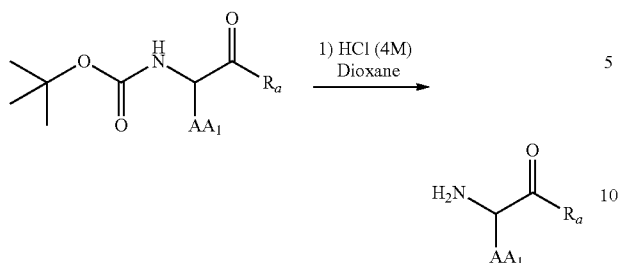


The above scheme and following description illustrates is representative method utilizing an azaindoline P2 component.

To the stirring solution of the ester compound (0.08 mmol) in ethanol (1 ml) was added solution of LiOH.H₂O (0.4 mmol) in water (0.5 ml). After stirring the reaction mixture for 5 hrs at RT, the mixture was acidified using citric acid (saturated solution) and concentrated under vacuum to give the crude product which was purified on a C18 column using 10-40% MeOH in water to yield product as an off-white solid (50-65%).

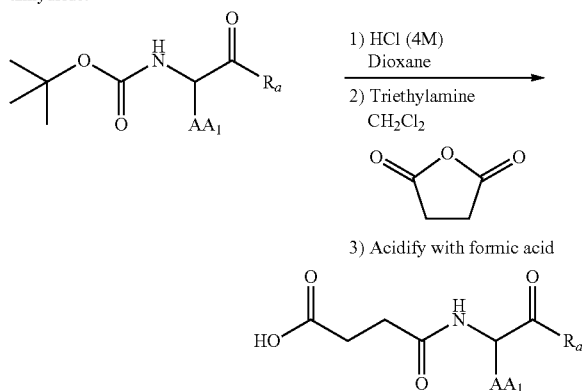
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Method D: General method for Boc deprotection.



HCl Solution in dioxane (4M, 0.5 ml) was added to the respective carbamate compound (0.06 mmol) and stirred for 3 hrs at RT. The reaction mixture was concentrated under vacuum to give the crude product which was purified on a C18 column using 10-40% MeOH in water to yield product as an off-white solid (50-60%).

Method E: General method for deprotectin followed by reaction with anhydride.



This method is an improved procedure for the method B. HCl Solution in dioxane (4 M, 5 ml) was added to a representative Boc-protected compound (0.125 mmol) and stirred for 2 hrs at RT. The reaction mixture was concentrated to dryness under vacuum and swapped with MeOH (5 ml) three times. The resulting residue was dried well under vacuum and subjected to next reaction as it was. The residue obtained above, the respective anhydride moiety (0.19 mmol, 1.5 eq.), and triethylamine (0.5 mmol, 4 eq.) were added to anhydrous DCM (5 mL) and stirred for 16 hrs. The mixture was acidified with formic acid and then concentrated under vacuum to give the crude product which was purified on a C18 column using 25-65% MeOH in water to yield product as an off-white solid (30-80%).

The following examples are provided for the purpose of illustrating, not limiting, the invention.

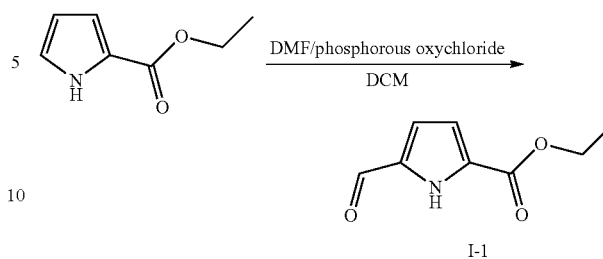
EXAMPLES

Synthetic Intermediates

The following is a description of synthetic intermediates (I-1 to I-10) useful for making representative compounds of the invention.

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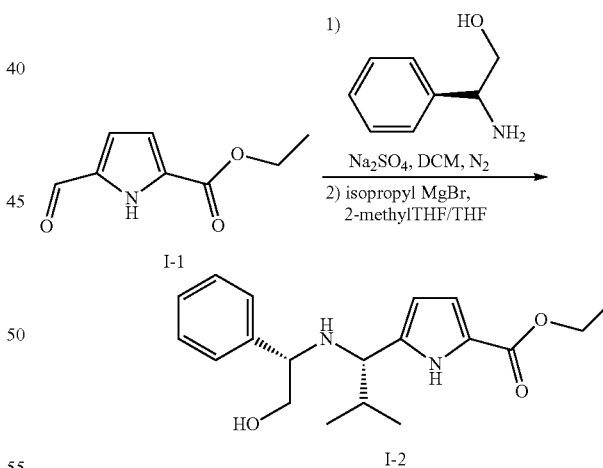
Intermediate I-1



Ethyl 5-formyl-1H-pyrrole-2-carboxylate (I-1)

To an ice cold solution of DMF (9.3 mL, 0.121 mmol, 1.12 eq.) in anhydrous DCM (23 mL) was added phosphorus oxychloride (11.1 mL, 0.120 mL, 1.11 eq.) dropwise. A solution of ethyl pyrrole-2-carboxylate (15 g, 0.108 mmol) in anhydrous DCM (23 mL) was then added slowly to the reaction mixture, which was stirred at 0° C. for 1 h and then heated to reflux for 3 hrs until no more starting material was seen on TLC. The reaction mixture was allowed to cool to RT, diluted with EtOAc (150 mL) and water (150 mL) and the washed with NaHCO₃ (saturated) (2×450 mL). The aqueous layer was re-extracted with ethyl acetate (3×150 mL) and the combined organic layers were dried over Na₂SO₄ and concentrated. The product was then purified by column chromatography using 5% to 30% ethyl acetate in hexanes as the eluent to give I-1 as a white solid (11.95 g, 66%). ¹H NMR (400 MHz, CDCl₃) δ 1.40 (3H, t, J=7 Hz), 4.39 (2H, q, J=7 Hz), 6.95 (2H, d, J=2 Hz), 9.68 (1H, s).

Intermediate I-2

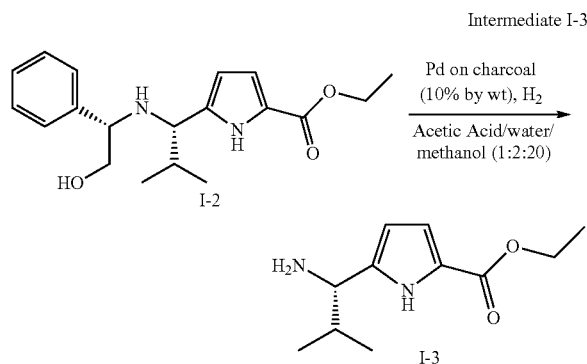


Ethyl 5-((S)-1-((S)-2-hydroxy-1-phenylethyl)amino)-2-methylpropyl-1H-pyrrole-2-carboxylate (I-2)

I-1 (5 g, 29.91 mmol) and L-phenylglycinol (4.10 g, 29.91 mmol) were dissolved in anhydrous DCM (120 mL) containing Na₂SO₄ (7.5 g) under N₂. The reaction mixture was stirred at RT for 16 hrs and was then filtered to remove Na₂SO₄. The filtrate was concentrated and dried well under vacuum. The pinkish obtained residue was dissolved in

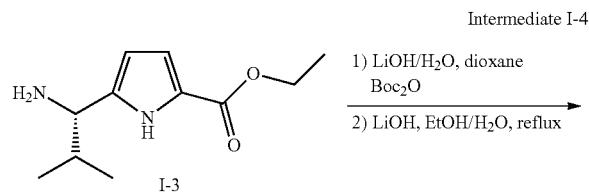
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anhydrous THF (150 mL) under N_2 and cooled to $-5^\circ C$. A solution of isopropyl magnesium bromide in 2-methyltetrahydrofuran (2.9 M, 46.4 mL, 134.6 mmol, 4.5 eq.) was then added dropwise. The reaction mixture turned greenish and then became dark brown. It was stirred at $0^\circ C$ for 1.5 h and then at RT for 48 hrs. The reaction mixture was then acidified by adding NH_4Cl (150 mL, saturated) and HCl (1 N, 150 mL, aqueous). The mixture was diluted with ethyl acetate (300 mL) and carefully basified until pH \approx 13 with $NaOH$ (1 N, aqueous). The organic phase was then collected and the aqueous phase was extracted with ethyl acetate (3 \times 300 mL). The combined organic layers were dried over Na_2SO_4 and concentrated. The product was then purified by column chromatography using 5% to 30% ethyl acetate in hexanes as the eluent to give I-2 as a yellow oil (3.07 g, 31%). 1H NMR (400 MHz, $CDCl_3$) δ 0.86 (3H, d, $J=6$ Hz), 0.95 (3H, d, $J=6$ Hz), 1.34 (3H, t, $J=7$ Hz), 1.99 (1H, m), 3.56 (1H, d, $J=6$ Hz), 3.62 (1H, dd, $J=8, 12$ Hz), 3.74-3.80 (2H, m), 4.26 (2H, q, $J=7$ Hz), 5.91 (1H, m), 6.75 (1H, m), 7.14-7.30 (5H, m), 9.12 (1H, s).



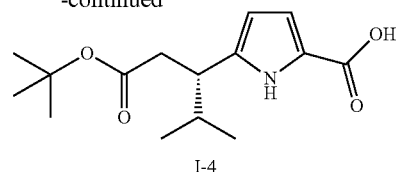
(S)-ethyl 5-(1-amino-2-methylpropyl)-1H-pyrrole-2-carboxylate (I-3)

I-2 (3.07 g, 9.291 mmol) was dissolved in a mixture of methanol/water/acetic acid (46 mL, 20:2:1 (v/v/v)) and palladium on charcoal 10% by wt (310 mg) was added to the solution under N_2 . The flask was then flushed with H_2 and H_2 was bubbled into the reaction mixture for 16 hrs. The flask was flushed with N_2 and the reaction mixture was filtered over CELITETM. The solids were washed with methanol (3 \times 100 mL) and the filtrate and washings were then concentrated to give I-3 as an orange oil (1.95 g, quantitative). 1H NMR (400 MHz, $CDCl_3$) δ 0.89 (3H, d, $J=6$ Hz), 0.92 (3H, d, $J=6$ Hz), 1.36 (3H, t, $J=7$ Hz), 1.94 (1H, m), 3.85 (1H, d, $J=6$ Hz), 4.31 (2H, q, $J=7$ Hz), 6.01 (1H, m), 6.87 (1H, m), 9.50 (1H, s).



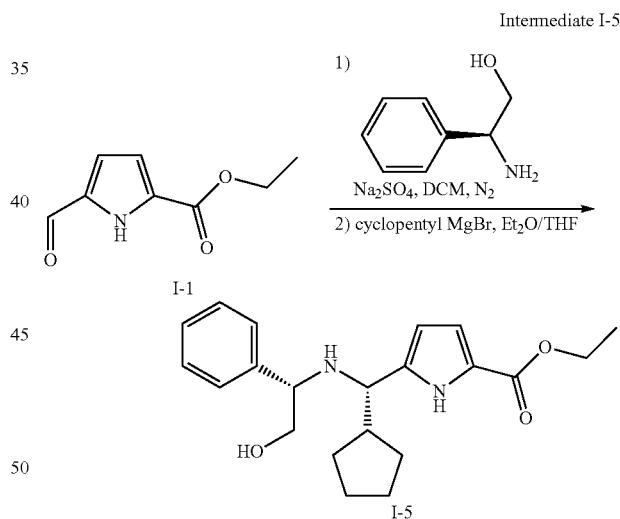
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(S)-5-(1-((tert-butoxycarbonyl)amino)-2-methylpropyl)-1H-pyrrole-2-carboxylic acid (I-4)

I-3 (1.78 g, 8.474 mmol) was dissolved in dioxane (50 mL) and a solution of $LiOH$ (356 mg, 8.474 mmol, 1 eq.) in water (10 mL) was added, followed by a solution of Boc_2O (2.03 g, 9.321 mmol, 1.1 eq.) in dioxane (25 mL). The reaction was left at RT for 1 h and the solvent was concentrated to give an orange oil which was dissolved in ethanol (40 mL) and was added a solution of $LiOH$ (2.13 g, 50.79 mmol, 6 eq.) in water (20 mL). The reaction mixture was heated to $70^\circ C$ for 4 hrs and was then acidified with citric acid (sat'd, aqueous) to pH 5. The solvents were then evaporated and the product was purified by column chromatography using 10% to 55% ethyl acetate in hexanes as the eluent to give I-4 as an orange solid (1.64 g, 68%). 1H NMR (400 MHz, $DMSO-d_6$) δ 0.68 (3H, d, $J=6$ Hz), 0.80 (3H, d, $J=6$ Hz), 1.35 (9H, s), 1.80 (1H, m), 4.37 (1H, t, $J=9$ Hz), 5.95 (1H, m), 6.60 (1H, m), 7.07 (1H, d, $J=10$ Hz), 11.3 (1H, s), 12.07 (1H, s).

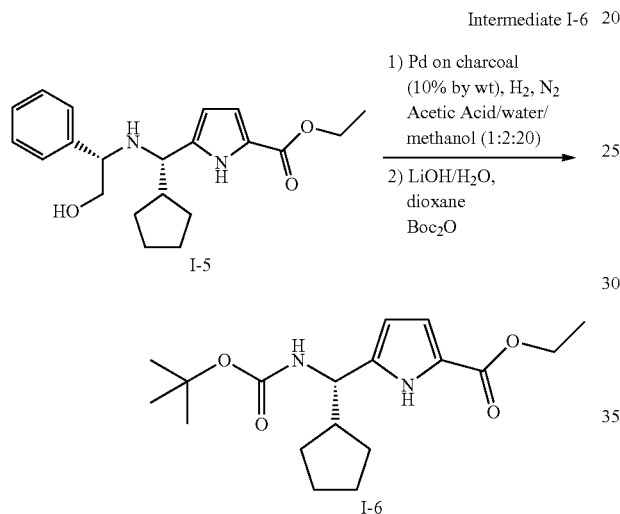


Ethyl 5-((S)-cyclopentyl)-1-((S)-2-hydroxy-1-phenylethylamino)-1H-pyrrole-2-carboxylate (I-5)

I-1 (4 g, 22.92 mmol) and L-phenylglycinol (3.28 g, 23.92 mmol) were dissolved in anhydrous DCM (100 mL) containing Na_2SO_4 (6 g) under N_2 . The reaction mixture was stirred at RT for 16 hrs and was then filtered to remove Na_2SO_4 . The filtrate was concentrated and dried well under vacuum. The pinkish obtained residue was dissolved in anhydrous THF (180 mL) under N_2 and cooled to $-5^\circ C$. A solution of cyclopentyl magnesium bromide in diethyl ether (2 M, 53.8 mL, 107.7 mmol, 4.5 eq.) was then added dropwise. The reaction mixture turned greenish and then

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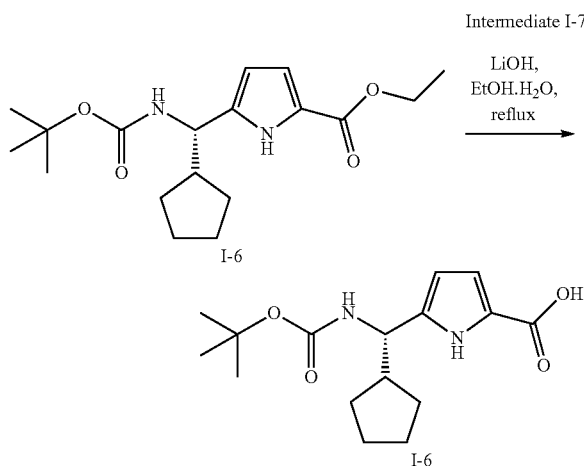
became dark brown. It was stirred at 0° C. for 1.5 h and then at RT for 48 hrs. The reaction mixture was then acidified by adding NH₄Cl (90 mL, sat'd, aqueous) and HCl (1 N, 90 mL). The mixture was diluted with ethyl acetate (200 mL) and carefully basified until pH ≈ 13 with NaOH (1 N, aqueous). The organic phase was then collected and the aqueous phase was extracted with ethyl acetate (3×200 mL). The combined organic layers were dried over Na₂SO₄ and concentrated. The product was then purified by column chromatography using 5% to 35% ethyl acetate in hexanes as the eluent to give I-5 as a orange oil (3.44 g, 40%). ¹H NMR (400 MHz, CDCl₃) δ 1.15 (1H, m), 1.34 (3H, t, J=7 Hz), 1.38 (1H, m), 1.43-1.65 (5H, m), 1.93 (1H, m), 2.15 (1H, m), 3.53-3.62 (2H, m), 3.70-3.79 (2H, m), 4.26 (2H, q, J=7 Hz), 5.92 (1H, m), 6.70 (1H, m), 7.14-7.24 (5H, m), 9.15 (1H, s).



(S)-ethyl 5-(((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carboxylate (I-6)

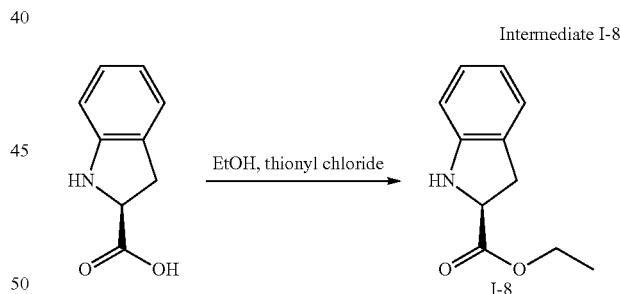
I-5 (3.44 g, 9.650 mmol) was dissolved in a mixture of methanol/water/acetic acid (60 mL, 20:2:1 (v/v/v)) and palladium on charcoal 10% by wt (350 mg) was added to the solution under N₂. The flask was then flushed with H₂ and H₂ was bubbled into the reaction mixture for 16 hrs. The flask was flushed with N₂ and the reaction mixture was filtered over CELITE™. The solids were washed with methanol (3×50 mL) and the filtrate and washings were then concentrated to give an orange oil that was dissolved in dioxane (75 mL) and a solution of LiOH (405 mg, 9.650 mmol, 1 eq.) in water (20 mL) was added, followed by a solution of Boc₂O (2.32 g, 10.62 mmol, 1.1 eq.) in dioxane (25 mL). The reaction was left at RT for 2 h and the solvent was concentrated. The product was then purified by column chromatography using 5% to 10% ethyl acetate in hexanes as the eluent to give I-6 as a orange oil (2.00 g, 62%). ¹H NMR (400 MHz, CDCl₃) δ 1.25 (1H, m), 1.34 (3H, t, J=7 Hz), 1.38-1.45 (10H, m), 1.51-1.72 (5H, m), 1.83 (1H, m), 2.35 (1H, m), 4.30 (2H, q, J=7 Hz), 4.46 (1H, m), 4.98 (1H, m), 6.05 (1H, m), 6.85 (1H, m), 9.63 (1H, s).

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(S)-5-(((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carboxylic acid (I-7)

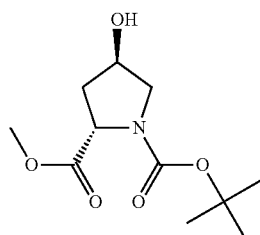
I-6 (2.00 g, 5.945 mmol, 1 eq.) was dissolved in ethanol (60 mL) and was added a solution of LiOH (1.50 g, 35.67 mmol, 6 eq.) in water (30 mL). The reaction mixture was heated to 70° C. for 4 hrs and was then acidified with a saturated solution of citric acid to pH 5. The solvents were then evaporated and the product was purified by column chromatography using 20% to 80% ethyl acetate in hexanes as the eluent to give I-7 as an orange solid (1.83 g, quantitative). ¹H NMR (400 MHz, DMSO-d₆) δ 1.10 (1H, m), 1.20-1.64 (16H, m), 2.10 (1H, m), 4.39 (1H, t, J=10 Hz), 5.98 (1H, m), 6.57 (1H, m), 7.09 (1H, d, J=10 Hz), 11.27 (1H, s), 12.07 (1H, s).



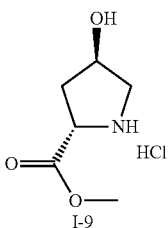
(S)-ethyl indoline-2-carboxylate hydrochloride (I-8)

(S)-indoline-2-carboxylic acid (500 mg, 306 mmol) was suspended in EtOH (5 mL) at 0° C. and thionyl chloride (0.450 mL, 6.127 mmol, 2 eq.) was added. The resulting clear mixture was allowed to come to RT and stirred for 16 hours. The reaction mixture was then concentrated to dryness and swapped with EtOH (2×10 mL). The solid obtained was dried well under reduced pressure to give a light brown solid (0.58 g, quantitative). ¹H NMR (400 MHz, DMSO-d₆) δ 1.18 (3H, s), 3.10-3.18 (1H, m), 3.30-3.40 (1H, m), 4.05-4.17 (2H, m), 4.55 (1H, bs), 6.80 (2H, bs), 7.02-7.08 (2H, m), 7.7 (2H, bs).

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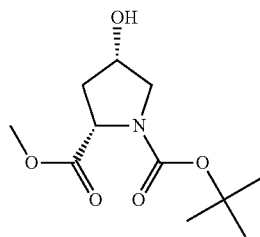


Method E

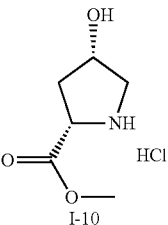


(2S,4R)-Methyl 4-hydroxypyrrolidine-2-carboxylate hydrochloride (I-9)

(2S,4R)-Methyl 4-hydroxypyrrolidine-2-carboxylate hydrochloride was prepared from Boc-trans-L-4-hydroxyproline methyl ester using method D. MS (LC/MS) m/z observed 146.00, expected 146.08 [M+H]. Compound was confirmed using LC/MS and moved to next step as it was.



Method E



(2S,4S)-Methyl 4-hydroxypyrrolidine-2-carboxylate hydrochloride (I-10)

(2S,4S)-Methyl 4-hydroxypyrrolidine-2-carboxylate hydrochloride was prepared from Boc-cis-L-4-hydroxyproline methyl ester using method D. MS (LC/MS) m/z observed 146.01, expected 146.08 [M+H]. Compound was confirmed using LC/MS and moved to next step as it was.

Representative Granzyme B Inhibitor Compounds

The following is a description of the preparation of representative Granzyme B inhibitor compounds of the invention.

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Examples C1-C9 were prepared by the representative synthetic pathway illustrated schematically in FIG. 3.

Example C1

3-{[2-methyl-1-{5-[(2S)-2-[(2H-1,2,3,4-tetrazol-5-ylmethyl)carbamoyl]-2,3-dihydro-1H-indole-1-carbonyl]-1H-pyrrol-2-yl}propyl]carbamoyl}propanoic acid

I-8 (318.4 mg, 1.403 mmol, 1.2 eq.) and HATU (533.5 mg, 1.403 mmol, 1.2 eq.) were dissolved in DCM (10 mL). To this mixture was added DIPEA (0.814 mL, 4.676 mmol, 4 eq.), followed by a solution of I-4 (330 mg, 1.169 mmol, 1 eq.) in DCM (5 mL) dropwise over 15 minutes. The reaction was left at RT for 2 hrs. The solvent was evaporated and the product was purified by column chromatography using 5% to 25% ethyl acetate in hexanes as the eluent to give (S)-ethyl 1-(5-((S)-1-((tert-butoxycarbonyl)amino)-2-methylpropyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylate as a white solid (247 mg, 46%). ^1H NMR (400 MHz, CDCl_3) δ 0.90-0.96 (6H, m), 1.17 (3H, t, $J=7$ Hz), 1.44 (9H, s), 2.10 (1H, m), 3.23 (1H, d, $J=17$ Hz), 3.66 (1H, dd, $J=11$, 16 Hz), 4.09-4.23 (2H, m), 4.54 (1H, m), 4.86 (1H, m), 5.33 (1H, d, $J=11$ Hz), 6.04 (1H, m), 6.48 (1H, m), 7.02 (1H, t, $J=7$ Hz), 7.15 (1H, d, $J=7$ Hz), 7.22 (1H, t, $J=8$ Hz), 8.15 (1H, d, $J=8$ Hz), 9.65 (1H, s). ^1H NMR confirmed the structure and it was used as was.

(S)-1-(5-((S)-1-((tert-butoxycarbonyl)amino)-2-methylpropyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylic acid was prepared from (S)-ethyl 1-(5-((S)-1-((tert-butoxycarbonyl)amino)-2-methylpropyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylate using method C with 2 eq. of $\text{LiOH}\cdot\text{H}_2\text{O}$. MS (LC/MS) m/z observed 427.97, expected 428.22 [M+H]. Compound was confirmed using LC/MS and moved to next step as it was.

tert-Butyl ((S)-1-(5-((S)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)indoline-1-carbonyl)-1H-pyrrol-2-yl)-2-methylpropyl)carbamate was prepared from (S)-1-(5-((S)-1-((tert-butoxycarbonyl)amino)-2-methylpropyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylic acid and (2H-tetrazol-5-yl)methylamine using method A in DMF but without HCl treatment. Compound was confirmed using LC/MS and moved to next step as it was.

Title compound 3-{[2-methyl-1-{5-[(2S)-2-[(2H-1,2,3,4-tetrazol-5-ylmethyl)carbamoyl]-2,3-dihydro-1H-indole-1-carbonyl]-1H-pyrrol-2-yl}propyl]carbamoyl}propanoic acid (C1) was prepared from tert-butyl ((S)-1-(5-((S)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)indoline-1-carbonyl)-1H-pyrrol-2-yl)-2-methylpropyl)carbamate and succinic anhydride using method E and separated by chromatography, into two diastereoisomers (C1-1 and C1-2).

C1-1
 ^1H NMR (400 MHz, $\text{DMSO}-d_6$) δ 0.72 (3H, d, $J=7$ Hz), 0.81 (3H, d, $J=7$ Hz), 1.90 (1H, m), 2.33-2.47 (4H, m), 3.12 (1H, d, $J=17$ Hz), 3.63 (1H, dd, $J=11$, 16 Hz), 4.38-4.59 (2H, m), 4.78 (1H, t, $J=9$ Hz), 5.33 (1H, d, $J=11$ Hz), 5.99 (1H, m), 6.44 (1H, m), 6.99 (1H, t, $J=7$ Hz), 7.17 (1H, d, $J=7$ Hz), 7.22 (1H, d, $J=8$ Hz), 8.02 (1H, d, $J=8$ Hz), 8.09 (1H, d, $J=8$ Hz), 8.92 (1H, bs), 11.30 (1H, s), MS (LC/MS) m/z observed 508.95, expected 509.23 [M+H].

C1-2
 ^1H NMR (400 MHz, $\text{DMSO}-d_6$) δ 0.72 (3H, d, $J=7$ Hz), 0.81 (3H, d, $J=7$ Hz), 1.90 (1H, m), 2.33-2.47 (4H, m), 3.12 (1H, d, $J=17$ Hz), 3.63 (1H, dd, $J=11$, 16 Hz), 4.43 (1H, dd, $J=5$, 11 Hz), 4.55 (1H, dd, $J=5$, 11 Hz), 4.78 (1H, t, $J=9$ Hz),

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5.33 (1H, d, J=11 Hz), 5.99 (1H, m), 6.44 (1H, m), 6.99 (1H, t, J=7 Hz), 7.17 (1H, d, J=7 Hz), 7.22 (1H, d, J=8 Hz), 8.02 (1H, d, J=8 Hz), 8.09 (1H, d, J=8 Hz), 8.92 (1H, bs), 11.30 (1H, s), MS (LC/MS) m/z observed 508.98, expected 509.23 [M+H].

Example C2

(2S)-1-{5-[2-methyl-1-(2-phenylacetamido)propyl]-1H-pyrrole-2-carbonyl}-N-(2H-1,2,3,4-tetrazol-5-ylmethyl)-2,3-dihydro-1H-indole-2-carboxamide

(S)-Ethyl 1-(5-((S)-1-((tert-butoxycarbonyl)amino)-2-methylpropyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylate (238.3 mg, 0.523 mmol, from Example C1) was suspended in HCl in dioxane (4 M, 15 mL) and the reaction mixture was stirred for 2 hrs at RT. The reaction mixture was then concentrated to dryness and swapped with MeOH (2x25 mL). The solid obtained was dried well under reduced pressure to give a brown residue that was dissolved in anhydrous DCM (15 mL) and added NEt₃ (0.292 mL, 2.092 mmol, 4 eq.). Phenylacetyl chloride (0.076 mL, 0.575 mmol, 1.1 eq.) was then added dropwise to the reaction mixture and it was stirred for 15 min at RT. The solvent was then concentrated and the product was purified by column chromatography using 5% to 45% ethyl acetate in hexanes as the eluent to give (S)-ethyl 1-(5-((S)-2-methyl-1-(2-phenylacetamido)propyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylate as a white solid (140 mg, 56%). ¹H NMR (400 MHz, DMSO-d₆) δ 0.71 (3H, d, J=7 Hz), 0.78 (3H, d, J=7 Hz), 1.09 (3H, t, J=7 Hz), 1.92 (1H, m), 3.16 (1H, d, J=16 Hz), 3.42-3.54 (2H, m), 3.69 (1H, m), 4.03-4.11 (2H, q, J=7 Hz), 4.79 (1H, t, J=8 Hz), 5.56 (1H, d, J=10 Hz), 6.04 (1H, m), 6.48 (1H, m), 7.02 (1H, t, J=7 Hz), 7.17-7.33 (6H, m), 8.07 (1H, d, J=8 Hz), 8.24 (1H, d, J=9 Hz), 11.42 (1H, s), MS (LC/MS) m/z observed 473.96, expected 474.24 [M+H]

(S)-1-(5-((S)-2-methyl-1-(2-phenylacetamido)propyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylic acid was prepared from (S)-ethyl 1-(5-((S)-2-methyl-1-(2-phenylacetamido)propyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylate using method C with 2 eq. of LiOH.H₂O. ¹H NMR (400 MHz, DMSO-d₆) δ 0.71 (3H, d, J=7 Hz), 0.78 (3H, d, J=7 Hz), 1.92 (1H, m), 3.16 (1H, d, J=16 Hz), 3.42-3.54 (2H, m), 3.67 (1H, dd, J=12, 17 Hz), 4.79 (1H, m), 5.39 (1H, d, J=11 Hz), 6.04 (1H, m), 6.48 (1H, m), 7.02 (1H, t, J=7 Hz), 7.16-7.32 (6H, m), 8.07 (1H, m), 8.24 (1H, t, J=9 Hz), 11.42 (1H, s), MS (LC/MS) m/z observed 445.97, expected 446.21 [M+H].

Title compound (2S)-1-{5-[2-methyl-1-(2-phenylacetamido)propyl]-1H-pyrrole-2-carbonyl}-N-(2H-1,2,3,4-tetrazol-5-ylmethyl)-2,3-dihydro-1H-indole-2-carboxamide (C2) was prepared from (S)-1-(5-((S)-2-methyl-1-(2-phenylacetamido)propyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylic acid and (2H-tetrazol-5-yl)methyl-amine using method A in DMF but without HCl treatment. An inseparable mixture of two diastereoisomers was obtained. ¹H NMR (400 MHz, DMSO-d₆) δ 0.68-0.82 (6H, m), 1.92 (1H, m), 3.13 (1H, m), 3.42-3.54 (2H, m), 3.65 (1H, m), 4.46 (1H, m), 4.56 (1H, dd, J=6, 16 Hz), 4.79 (1H, m), 5.33 (1H, d, J=11 Hz), 6.00 (1H, m), 6.43 (1H, m), 6.98 (1H, t, J=7 Hz), 7.16-7.32 (6H, m), 8.03 (1H, m), 8.24 (1H, m), 9.02 (1H, bs), 11.35 (1H, s), MS (LC/MS) m/z observed 526.95, expected 527.25 [M+H].

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Example C3

3-{[2-methyl-1-[5-({[(2H-1,2,3,4-tetrazol-5-ylmethyl)carbamoyl]methyl}carbamoyl)-1H-pyrrol-2-yl]propyl]carbamoyl}propanoic acid

Glycine ethyl ester hydrochloride (207.8 mg, 1.489 mmol, 1.2 eq.), HOBt (227.8 mg, 1.489 mmol, 1.2 eq.) and EDC (309.3 mg, 1.616 mmol, 1.3 eq.) were dissolved in DCM (10 mL). To this mixture was added DIPEA (0.864 mL, 4.964 mmol, 4 eq.), followed by a solution of 1-4 (350 mg, 1.241 mmol, 1 eq.) in DCM (5 mL) dropwise over 15 minutes. The reaction was left at RT for 2 hrs. The solvent was evaporated and the product was purified by column chromatography using 5% to 35% ethyl acetate in hexanes as the eluent to give (S)-{[5-(1-tert-butoxycarbonylamino-2-methyl-propyl)-1H-pyrrole-2-carbonyl]-amino}-acetic acid ethyl ester as a white solid (225 mg, 49%). ¹H NMR (400 MHz, CDCl₃) δ 0.82 (3H, d, J=7 Hz), 0.94 (3H, d, J=7 Hz), 1.30 (3H, t, J=7 Hz), 1.43 (9H, s), 2.00 (1H, m), 4.22-4.28 (4H, m), 4.52 (1H, m), 5.78 (1H, d, J=17 Hz), 6.04 (1H, m), 6.43 (1H, m), 6.58 (1H, m), 10.37 (1H, s). ¹H NMR confirmed the structure and the product was used as it was.

{[5-(1-tert-Butoxycarbonylamino-2-methyl-propyl)-1H-pyrrole-2-carbonyl]-amino}-acetic acid was prepared from (S)-{[5-(1-tert-butoxycarbonylamino-2-methyl-propyl)-1H-pyrrole-2-carbonyl]-amino}-acetic acid ethyl ester using method C with 2 eq. of LiOH.H₂O. ¹H NMR (400 MHz, DMSO-d₆) δ 0.67 (3H, d, J=7 Hz), 0.84 (3H, d, J=7 Hz), 1.36 (9H, s), 1.86 (1H, m), 3.60-3.80 (2H, m), 4.30 (1H, t, J=9 Hz), 5.89 (1H, m), 6.58 (1H, m), 7.98 (1H, s). ¹H NMR confirmed the structure and the compound was used as it was.

(S)-tert-Butyl (1-(5-((2-((2H-tetrazol-5-yl)methyl)amino)-2-oxoethyl)carbamoyl)-1H-pyrrol-2-yl)-2-methyl-propylcarbamate was prepared from {[5-(1-tert-butoxycarbonylamino-2-methyl-propyl)-1H-pyrrole-2-carbonyl]-amino}-acetic acid and (2H-tetrazol-5-yl)methyl-amine using method A in DMF but without HCl treatment. MS (LC/MS) m/z observed 420.99, expected 421.23 [M+H]. Compound was confirmed using LC/MS and moved to next step as it was.

Title compound 3-{[2-methyl-1-[5-({[(2H-1,2,3,4-tetrazol-5-ylmethyl)carbamoyl]methyl}carbamoyl)-1H-pyrrol-2-yl]propyl]carbamoyl}propanoic acid (C3) was prepared from (S)-tert-butyl (1-(5-((2-((2H-tetrazol-5-yl)methyl)amino)-2-oxoethyl)carbamoyl)-1H-pyrrol-2-yl)-2-methyl-propylcarbamate and succinic anhydride using method E and obtained as a mixture of two enantiomers. ¹H NMR (400 MHz, DMSO-d₆) δ 0.72 (3H, d, J=7 Hz), 0.81 (3H, d, J=7 Hz), 1.87 (1H, m), 2.30-2.47 (4H, m), 3.82-3.92 (2H, m), 4.56 (2H, d, J=6 Hz), 4.74 (1H, t, J=9 Hz), 5.95 (1H, m), 6.72 (1H, m), 8.02 (1H, d, J=10 Hz), 8.23 (1H, t, J=8 Hz), 8.63 (1H, d, J=6 Hz), 11.12 (1H, bs.), MS (LC/MS) m/z observed 420.96, expected 421.19 [M+H]

Example C4

3-{[2-methyl-1-{5-[(2S)-2-[(2H-1,2,3,4-tetrazol-5-ylmethyl)carbamoyl]pyrrolidine-1-carbonyl]-1H-pyrrol-2-yl]propyl]carbamoyl}propanoic acid

Proline ethyl ester hydrochloride (271.1 mg, 1.509 mmol, 1.2 eq.) and HATU (573.7 mg, 1.509 mmol, 1.2 eq.) were dissolved in DMF (15 mL). To this mixture was added DIPEA (0.875 mL, 5.028 mmol, 4 eq.), followed by a solution of 1-4 (355 mg, 1.257 mmol, 1 eq.) in DMF (5 mL)

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dropwise over 15 minutes. The reaction was left at RT for 2 hrs. The solvent was evaporated and the product was purified by column chromatography using 5% to 35% ethyl acetate in hexanes as the eluent to give (S)-ethyl 1-(5-((S)-1-((tert-butoxycarbonyl)amino)-2-methylpropyl)-1H-pyrrole-2-carbonyl)pyrrolidine-2-carboxylate as a white solid (344 mg, 67%). ¹H NMR (400 MHz, CDCl₃) δ 0.88-0.94 (6H, m), 1.23-1.31 (3H, m), 1.43 (9H, m), 1.95-2.30 (5H, m), 3.83 (1H, m), 3.93 (1H, m), 4.18-4.28 (2H, m), 4.55 (1H, m), 4.66 (1H, m), 4.86 (1H, m), 6.05 (1H, m), 6.57 (1H, m), 9.48 (1H, s). ¹H NMR confirmed the structure and it was used further as it was.

(S)-1-(5-((S)-1-((tert-butoxycarbonyl)amino)-2-methylpropyl)-1H-pyrrole-2-carbonyl)pyrrolidine-2-carboxylic acid was prepared from (S)-ethyl 1-(5-((S)-1-((tert-butoxycarbonyl)amino)-2-methylpropyl)-1H-pyrrole-2-carbonyl)pyrrolidine-2-carboxylate using method C with 2 eq. of LiOH.H₂O. MS (LC/MS) m/z observed 379.99, expected 380.22 [M+H]. Compound was confirmed using LC/MS and moved to next step as it was.

tert-Butyl ((S)-1-(5-((S)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)pyrrolidine-1-carbonyl)-1H-pyrrol-2-yl)-2-methylpropyl)carbamate was prepared from (S)-1-(5-((S)-1-((tert-butoxycarbonyl)amino)-2-methylpropyl)-1H-pyrrole-2-carbonyl)pyrrolidine-2-carboxylic acid and (2H-tetrazol-5-yl)methyl-amine using method A in DMF but without HCl treatment. MS (LC/MS) m/z observed 460.98, expected 461.26 [M+H]. Compound was confirmed using LC/MS and moved to next step as it was.

Title compound 3-{[2-methyl-1-{5-[(2S)-2-[(2H-1,2,3,4-tetrazol-5-ylmethyl)carbamoyl]pyrrolidine-1-carbonyl]-1H-pyrrol-2-yl}]propyl]carbamoyl}propanoic acid (C4) was prepared from tert-butyl ((S)-1-(5-((S)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)pyrrolidine-1-carbonyl)-1H-pyrrol-2-yl)-2-methylpropyl)carbamate and succinic anhydride using method E. An inseparable mixture of two diastereoisomers was obtained. ¹H NMR (400 MHz, DMSO-d₆) δ 0.72 (3H, d, J=7 Hz), 0.81 (3H, d, J=7 Hz), 1.82-2.00 (5H, m), 2.28-2.45 (4H, m), 3.68-3.87 (2H, m), 4.45-4.57 (3H, m), 4.77 (1H, t, J=8 Hz), 6.02 (1H, m), 6.58 (1H, m), 8.05 (1H, dd, J=3, 10 Hz), 8.65 (1H, s), 11.10 (1H, s), MS (LC/MS) m/z observed 460.97, expected 461.23 [M+H]

Example C5

3-{[cyclopentyl{5-[(2S)-2-[(2H-1,2,3,4-tetrazol-5-ylmethyl)carbamoyl]-2,3-dihydro-1H-indole-1-carbonyl]-1H-pyrrol-2-yl}]methyl]carbamoyl}propanoic acid

I-8 (516.7 mg, 2.276 mmol, 1.2 eq.) and HATU (865.4 mg, 2.276 mmol, 1.2 eq.) were dissolved in DCM (20 mL). To this mixture was added DIPEA (1.32 mL, 7.588 mmol, 4 eq.), followed by a solution of I-7 (585 mg, 1.897 mmol, 1 eq.) in DCM (10 mL) dropwise over 15 minutes. The reaction was left at RT for 2 hrs. The solvent was evaporated and the product was purified by column chromatography using 5% to 20% ethyl acetate in hexanes as the eluent to give (S)-ethyl 1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylate as a white solid (448 mg, 49%). ¹H NMR (400 MHz, CDCl₃) δ 1.16 (3H, t, J=6 Hz), 1.25 (1H, m), 1.35-1.47 (10H, m), 1.51-1.72 (5H, m), 1.82 (1H, m), 2.32 (1H, m), 3.23 (1H, d, J=17 Hz), 3.66 (1H, dd, J=11, 16 Hz), 4.09-4.23 (2H, m), 4.54 (1H, m), 4.86 (1H, m), 5.34 (1H, d, J=11 Hz), 6.06 (1H, m), 6.48 (1H, m), 7.02 (1H, t, J=7 Hz), 7.17 (1H, d, J=7 Hz), 7.22 (1H, t, J=8 Hz), 8.15 (1H, d, J=8

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Hz), 9.70 (1H, s). ¹H NMR confirmed the structure and the product was used further as it was.

(S)-1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylic acid was prepared from (S)-ethyl 1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylate using method C with 2 eq. of LiOH.H₂O. MS (LC/MS) m/z observed 453.89, expected 454.23 [M+H]. Compound was confirmed using LC/MS and moved to next step as it was.

tert-Butyl ((S)-1-(5-((S)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)indoline-1-carbonyl)-1H-pyrrol-2-yl)(cyclopentyl)methyl)carbamate was prepared from (S)-1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylic acid and (2H-tetrazol-5-yl)methyl-amine using method A in DMF but without HCl treatment. MS (LC/MS) m/z observed 556.97, expected 557.26 [M+Na]. Compound was confirmed using LC/MS and moved to next step as it was.

Title compound 3-{[cyclopentyl{5-[(2S)-2-[(2H-1,2,3,4-tetrazol-5-ylmethyl)carbamoyl]-2,3-dihydro-1H-indole-1-carbonyl]-1H-pyrrol-2-yl}]methyl]carbamoyl}propanoic acid (C5) was prepared from tert-butyl ((S)-1-(5-((S)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)indoline-1-carbonyl)-1H-pyrrol-2-yl)(cyclopentyl)methyl)carbamate and succinic anhydride using method E and were separated by chromatography, into two diastereoisomers (C5-1 and C5-2).

¹H NMR (400 MHz, DMSO-d₆) δ 1.10-1.65 (8H, m), 2.15 (1H, m), 2.27-2.45 (4H, m), 3.12 (1H, d, J=17 Hz), 3.63 (1H, dd, J=11, 16 Hz), 4.41 (1H, dd, J=5, 16 Hz), 4.55 (1H, dd, J=5, 16 Hz), 4.78 (1H, t, J=9 Hz), 5.33 (1H, d, J=11 Hz), 5.98 (1H, m), 6.37 (1H, m), 6.98 (1H, t, J=7 Hz), 7.15 (1H, d, J=7 Hz), 7.21 (1H, d, J=8 Hz), 7.98 (1H, d, J=8 Hz), 8.13 (1H, d, J=8 Hz), 8.97 (1H, bs), 11.23 (1H, s), MS (LC/MS) m/z observed 534.88, expected 535.24 [M+H].

C5-2
¹H NMR (400 MHz, DMSO-d₆) δ 1.10-1.65 (8H, m), 2.15 (1H, m), 2.27-2.45 (4H, m), 3.12 (1H, d, J=17 Hz), 3.63 (1H, dd, J=11, 16 Hz), 4.41 (1H, dd, J=5, 16 Hz), 4.55 (1H, dd, J=5, 16 Hz), 4.78 (1H, t, J=9 Hz), 5.33 (1H, d, J=11 Hz), 5.98 (1H, m), 6.37 (1H, m), 6.98 (1H, t, J=7 Hz), 7.15 (1H, d, J=7 Hz), 7.21 (1H, d, J=8 Hz), 7.98 (1H, d, J=8 Hz), 8.13 (1H, d, J=8 Hz), 8.97 (1H, bs), 11.23 (1H, s), MS (LC/MS) m/z observed 534.88, expected 535.24 [M+H].

Example C6

(2S)-1-{5-[cyclopentyl(2-phenylacetamido)methyl]-1H-pyrrole-2-carbonyl]-N-(2H-1,2,3,4-tetrazol-5-ylmethyl)-2,3-dihydro-1H-indole-2-carboxamide

(S)-Ethyl 1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylate (200 mg, 0.415 mmol, from Example C5) was suspended in HCl in dioxane (4 M, 15 mL) and the reaction mixture was stirred for 2 hrs at RT. The reaction mixture was then concentrated to dryness and swapped with MeOH (2×25 mL). The solid obtained was dried well under reduced pressure to give a brown residue that was dissolved in anhydrous DCM (15 mL) and added NEt₃ (0.231 mL, 1.660 mmol, 4 eq.). Phenylacetyl chloride (0.060 mL, 0.457 mmol, 1.1 eq.) was then added dropwise to the reaction mixture and it was stirred for 15 min at RT. The solvent was then concentrated and the product was purified by column chromatography using 5% to 40% ethyl acetate in hexanes as the eluent to give (S)-ethyl 1-(5-((S)-cyclopentyl(2-phenylacet-

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amido)methyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylate as a white solid (140 mg, 46%). ¹H NMR (400 MHz, DMSO-d₆) δ 1.08 (3H, t, J=7 Hz), 1.10-1.60 (8H, m), 2.16 (1H, m), 3.15 (1H, d, J=17 Hz), 3.35-3.48 (2H, m), 3.65 (1H, dd, J=11, 16 Hz), 4.05 (2H, q, J=7 Hz), 4.78 (1H, t, J=9 Hz), 5.52 (1H, d, J=11 Hz), 6.03 (1H, m), 6.43 (1H, m), 6.98 (1H, t, J=7 Hz), 7.15-7.30 (6H, m), 8.04 (1H, d, J=8 Hz), 8.28 (1H, d, J=9 Hz), 11.23 (1H, s), MS (LC/MS) m/z observed 499.89, expected 500.25 [M+H]

(S)-1-(5-((S)-Cyclopentyl(2-phenylacetamido)methyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylic acid was prepared from (S)-ethyl 1-(5-((S)-cyclopentyl(2-phenylacetamido)methyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylate using method C with 2 eq. of LiOH.H₂O. MS (LC/MS) m/z observed 471.86, expected 472.22 [M+H]. Compound was confirmed using LC/MS and moved to next step as it was.

Title compound (2S)-1-[5-[cyclopentyl(2-phenylacetamido)methyl]-1H-pyrrole-2-carbonyl]-N-(2H-1,2,3,4-tetrazol-5-ylmethyl)-2,3-dihydro-1H-indole-2-carboxamide (C6) was prepared from (S)-1-(5-((S)-cyclopentyl(2-phenylacetamido)methyl)-1H-pyrrole-2-carbonyl)indoline-2-carboxylic acid and (2H-tetrazol-5-yl)methylamine using method A in DMF but without HCl treatment and were separated by chromatography, into two diastereoisomers (C6-1 and C6-2).

C6-1

¹H NMR (400 MHz, DMSO-d₆) δ 1.10-1.60 (8H, m), 2.20 (1H, m), 3.12 (1H, d, J=17 Hz), 3.35-3.48 (2H, m), 3.60 (1H, dd, J=11, 16 Hz), 4.38 (1H, dd, J=5, 17 Hz), 4.53 (1H, dd, J=5, 17 Hz), 4.78 (1H, t, J=9 Hz), 5.32 (1H, d, J=11 Hz), 5.98 (1H, m), 6.42 (1H, m), 6.97 (1H, t, J=7 Hz), 7.15-7.30 (6H, m), 8.00 (1H, d, J=8 Hz), 8.28 (1H, d, J=9 Hz), 8.86 (1H, bs), 11.28 (1H, s), MS (LC/MS) m/z observed 552.85, expected 553.27 [M+H].

C6-2

MS (LC/MS) m/z observed 552.87, expected 553.27 [M+H].

Example C7

3-[[cyclopentyl({5-[(2S,4R)-4-hydroxy-2-[(2H-1,2,3,4-tetrazol-5-ylmethyl)carbamoyl]pyrrolidine-1-carbonyl]-1H-pyrrol-2-yl})methyl]carbamoyl]propanoic acid

I-9 (282.6 mg, 1.556 mmol, 1.2 eq.) and HATU (591.6 mg, 1.556 mmol, 1.2 eq.) were dissolved in DMF (15 mL). To this mixture was added DIPEA (0.903 mL, 5.188 mmol, 4 eq.), followed by a solution of I-7 (400 mg, 1.297 mmol, 1 eq.) in DMF (5 mL) dropwise over 15 minutes. The reaction was left at RT for 2 hrs. The solvent was evaporated and the product was purified by column chromatography using 5% to 50% ethyl acetate in hexanes as the eluent to give (2S,4R)-methyl 1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)-4-hydroxypyrrolidine-2-carboxylate as a white solid (201.9 mg, 36%). ¹H NMR (400 MHz, DMSO-d₆) δ 1.10 (1H, m), 1.20-1.65 (15H, m), 1.86 (1H, m), 2.10 (1H, m), 2.32 (1H, m), 3.50 (1H, m), 3.59 (3H, s), 3.92 (1H, m), 4.32-4.41 (2H, m), 4.54 (1H, m), 5.12 (1H, bs), 6.06 (1H, m), 6.52 (1H, m), 7.16 (1H, d, J=10 Hz), 11.04 (1H, s), MS (LC/MS) m/z observed 435.85, expected 436.24 [M+H]

(2S,4R)-1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)-4-hydroxypyrrolidine-2-carboxylic acid was prepared from (2S,4R)-methyl 1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)

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methyl)-1H-pyrrole-2-carbonyl)-4-hydroxypyrrolidine-2-carboxylate using method C with 2 eq. of LiOH.H₂O. ¹H NMR (400 MHz, DMSO-d₆) δ 1.10 (1H, m), 1.20-1.65 (15H, m), 1.82 (1H, m), 2.10 (2H, m), 2.32 (1H, m), 3.50 (1H, m), 3.92 (1H, m), 4.30-4.40 (2H, m), 4.48 (1H, m), 6.00 (1H, m), 6.48 (1H, m), 7.19 (1H, d, J=10 Hz), 11.02 (1H, s), MS (LC/MS) m/z observed 421.85, expected 422.23 [M+H].

tert-Butyl ((S)-5-((2S,4R)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)-4-hydroxypyrrolidine-1-carbonyl)-1H-pyrrol-2-yl)(cyclopentyl)methylcarbamate was prepared from (2S,4R)-1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)-4-hydroxypyrrolidine-2-carboxylic acid and (2H-tetrazol-5-yl)methylamine using method A in DMF but without HCl treatment. MS (LC/MS) m/z observed 502.87, expected 503.27 [M+H]. Compound was confirmed using LC/MS and moved to next step as it was.

Title compound 3-[[cyclopentyl({5-[(2S,4R)-4-hydroxy-2-[(2H-1,2,3,4-tetrazol-5-ylmethyl)carbamoyl]pyrrolidine-1-carbonyl]-1H-pyrrol-2-yl})methyl]carbamoyl]propanoic acid (C7) was prepared from tert-butyl ((S)-5-((2S,4R)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)-4-hydroxypyrrolidine-1-carbonyl)-1H-pyrrol-2-yl)(cyclopentyl)methylcarbamate and succinic anhydride using method E and were separated by chromatography, into two diastereoisomers (C7-1 and C7-2).

C7-1

¹H NMR (400 MHz, DMSO-d₆) δ 1.15 (1H, m), 1.20-1.65 (7H, m), 1.90 (1H, m), 2.05 (1H, m), 2.16 (1H, m), 2.24-2.43 (4H, m), 3.65 (1H, d, J=10 Hz), 3.86 (1H, m), 4.36 (1H, s), 4.48-4.58 (2H, m), 4.78 (1H, t, J=9 Hz), 5.08 (1H, bs), 6.02 (1H, s), 6.50 (1H, s), 8.10 (1H, d, J=10 Hz), 8.71 (1H, m), 11.08 (1H, s), MS (LC/MS) m/z observed 502.93, expected 503.24 [M+H].

C7-2

¹H NMR (400 MHz, DMSO-d₆) δ 1.15 (1H, m), 1.20-1.65 (7H, m), 1.85 (1H, m), 2.15 (1H, m), 2.23-2.34 (3H, m), 2.35-2.43 (2H, m), 3.60 (1H, m), 3.92 (1H, m), 4.32 (1H, bs), 4.48-4.58 (3H, m), 4.78 (1H, t, J=9 Hz), 6.02 (1H, s), 6.52 (1H, s), 8.10 (1H, d, J=10 Hz), 8.78 (1H, m), 11.08 (1H, s), MS (LC/MS) m/z observed 502.89, expected 503.24 [M+H].

Example C8

3-[[cyclopentyl({5-[(2S,4S)-4-hydroxy-2-[(2H-1,2,3,4-tetrazol-5-ylmethyl)carbamoyl]pyrrolidine-1-carbonyl]-1H-pyrrol-2-yl})methyl]carbamoyl]propanoic acid

I-10 (282.6 mg, 1.556 mmol, 1.2 eq.) and HATU (591.6 mg, 1.556 mmol, 1.2 eq.) were dissolved in DMF (15 mL). To this mixture was added DIPEA (0.903 mL, 5.188 mmol, 4 eq.), followed by a solution of I-7 (400 mg, 1.297 mmol, 1 eq.) in DMF (5 mL) dropwise over 15 minutes. The reaction was left at RT for 2 hrs. The solvent was evaporated and the product was purified by column chromatography using 5% to 50% ethyl acetate in hexanes as the eluent to give (2S,4S)-methyl 1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)-4-hydroxypyrrolidine-2-carboxylate as a white solid (182.8 mg, 32%). ¹H NMR (400 MHz, DMSO-d₆) δ 1.10 (1H, m), 1.20-1.65 (15H, m), 1.82 (1H, m), 2.05-2.15 (2H, m), 3.60 (3H, s), 3.64 (1H, d, J=11 Hz), 3.85 (1H, m), 4.32-4.41 (2H, m), 4.52 (1H, t, J=9 Hz), 5.15 (1H, bs), 6.01 (1H, m), 6.52 (1H, m), 7.14 (1H, d, J=10 Hz), 11.07 (1H, s), MS (LC/MS) m/z observed 435.84, expected 436.24 [M+H]

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(2S,4S)-1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)-4-hydroxypyrrolidine-2-carboxylic acid was prepared from (2S,4S)-methyl 1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)-4-hydroxypyrrolidine-2-carboxylate using method C with 2 eq. of LiOH.H₂O. ¹H NMR (400 MHz, DMSO-d₆) δ 1.10 (1H, m), 1.20-1.65 (15H, m), 1.82 (1H, m), 2.10 (2H, m), 2.32 (1H, m), 3.50 (1H, m), 3.92 (1H, m), 4.30-4.40 (2H, m), 4.48 (1H, m), 6.00 (1H, m), 6.48 (1H, m), 7.19 (1H, d, J=10 Hz), 11.02 (1H, s), MS (LC/MS) m/z observed 421.81, expected 422.23 [M+H].

tert-Butyl ((S)-5-((2S,4S)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)-4-hydroxypyrrolidine-1-carbonyl)-1H-pyrrol-2-yl)(cyclopentyl)methyl)carbamate was prepared from (2S,4S)-1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)-4-hydroxypyrrolidine-2-carboxylic acid and (2H-tetrazol-5-yl)methyl-amine using method A in DMF but without HCl treatment. MS (LC/MS) m/z observed 502.87, expected 503.27 [M+H]. Compound was confirmed using LC/MS and moved to next step as it was.

Title compound 3-[(cyclopentyl){5-[(2S,4S)-4-hydroxy-2-[(2H-1,2,3,4-tetrazol-5-yl)methyl]carbamoyl]pyrrolidine-1-carbonyl]-1H-pyrrol-2-yl)methyl]carbamoyl]propanoic acid (C8) was prepared from tert-butyl ((S)-5-((2S,4S)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)-4-hydroxypyrrolidine-1-carbonyl)-1H-pyrrol-2-yl)(cyclopentyl)methyl)carbamate and succinic anhydride using method E and were separated by chromatography, into two diastereoisomers (C8-1 and C8-2).

C8-1

¹H NMR (400 MHz, DMSO-d₆) δ 1.15 (1H, m), 1.20-1.65 (7H, m), 1.90 (1H, m), 2.05 (1H, m), 2.16 (1H, m), 2.24-2.43 (4H, m), 3.65 (1H, d, J=10 Hz), 3.86 (1H, m), 4.36 (1H, s), 4.48-4.58 (2H, m), 4.78 (1H, t, J=9 Hz), 5.08 (1H, bs), 6.02 (1H, s), 6.50 (1H, s), 8.10 (1H, d, J=10 Hz), 8.67 (1H, m), 11.08 (1H, s), MS (LC/MS) m/z observed 502.91, expected 503.24 [M+H].

C8-2

¹H NMR (400 MHz, DMSO-d₆) δ 1.15 (1H, m), 1.20-1.65 (7H, m), 1.85 (1H, m), 2.15 (1H, m), 2.23-2.34 (3H, m), 2.35-2.43 (2H, m), 3.60 (1H, m), 3.92 (1H, m), 4.32 (1H, bs), 4.48-4.58 (3H, m), 4.78 (1H, t, J=9 Hz), 6.02 (1H, s), 6.52 (1H, s), 8.10 (1H, d, J=10 Hz), 8.78 (1H, m), 11.08 (1H, s), MS (LC/MS) m/z observed 502.90, expected 503.24 [M+H].

Example C9

3-[(5-[(2S,4S)-4-cyclohexyl-2-[(2H-1,2,3,4-tetrazol-5-yl)methyl]carbamoyl]pyrrolidine-1-carbonyl]-1H-pyrrol-2-yl)(cyclopentyl)methyl]carbamoyl]propanoic acid

trans-4-Cyclohexyl-L-proline hydrochloride (450 mg, 1.925 mmol) was suspended in EtOH (5 mL) at 0° C. and thionyl chloride (0.280 mL, 3.850 mmol, 2 eq.) was added dropwise. The resulting clear mixture was allowed to come to RT and stirred for 16 hours. The reaction mixture was then concentrated to dryness and swapped with EtOH (2×10 mL). The solid obtained was dried well under reduced pressure to give (2S,4S)-ethyl 4-cyclohexylpyrrolidine-2-carboxylate hydrochloride as a white solid (504 mg, quantitative). ¹H NMR (400 MHz, DMSO-d₆) δ 0.68-0.80 (2H, m), 0.88-1.12 (7H, m), 1.38-1.55 (5H, m), 1.70-1.82 (2H, m), 2.00 (1H, m), 2.34 (2H, m), 2.66 (1H, t, J=9 Hz), 4.01-4.09 (2H, m), 4.26 (1H, m), MS (LC/MS) m/z observed 226.09, expected 226.18 [M+H].

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(2S,4S)-Ethyl 4-cyclohexylpyrrolidine-2-carboxylate hydrochloride (560 mg, 2.139 mmol, 1.2 eq.) and HATU (814.5 mg, 2.139 mmol, 1.2 eq.) were dissolved in DCM (20 mL). To this mixture was added DIPEA (1.24 mL, 7.140 mmol, 4 eq.), followed by a solution of I-7 (550 mg, 1.785 mmol, 1 eq.) in DCM (5 mL) dropwise over 15 minutes. The reaction was left at RT for 2 hrs. The solvent was evaporated and the product was purified by column chromatography using 5% to 30% ethyl acetate in hexanes as the eluent to give (2S,4S)-ethyl 1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)-4-cyclohexylpyrrolidine-2-carboxylate as an orange solid (715.9 mg, 78%). ¹H NMR (400 MHz, CDCl₃) δ 0.92-1.06 (2H, m), 1.13-1.30 (8H, m), 1.35-1.45 (10H, m), 1.48-1.85 (12H, m), 2.12 (1H, m), 2.20-2.32 (2H, m), 3.37 (1H, t, J=10 Hz), 4.10 (1H, m), 4.21 (2H, q, J=8 Hz), 4.50 (1H, m), 4.72 (1H, d, J=9 Hz), 5.05 (1H, m), 6.06 (1H, m), 6.53 (1H, m), 9.80 (1H, s). MS (LC/MS) m/z observed 515.93, expected 516.34 [M+H].

(2S,4S)-1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)-4-cyclohexylpyrrolidine-2-carboxylic acid was prepared from (2S,4S)-ethyl 1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)-4-cyclohexylpyrrolidine-2-carboxylate using method C with 4 eq. of LiOH.H₂O. ¹H NMR (400 MHz, DMSO-d₆) δ 0.87-1.01 (2H, m), 1.05-1.75 (27H, m), 1.97 (1H, m), 2.10 (1H, m), 2.37 (1H, m), 3.33 (1H, m), 3.96 (1H, t, J=9 Hz), 4.27-4.44 (2H, m), 6.02 (1H, m), 6.53 (1H, m), 7.19 (1H, d, J=10 Hz), 11.2 (1H, s), 12.40 (1H, bs). MS (LC/MS) m/z observed 487.90, expected 488.31 [M+H].

tert-Butyl ((S)-5-((2S,4S)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)-4-cyclohexylpyrrolidine-1-carbonyl)-1H-pyrrol-2-yl)(cyclopentyl)methyl)carbamate was prepared from (2S,4S)-ethyl 1-(5-((S)-((tert-butoxycarbonyl)amino)(cyclopentyl)methyl)-1H-pyrrole-2-carbonyl)-4-cyclohexylpyrrolidine-2-carboxylate and (2H-tetrazol-5-yl)methyl-amine using method A in DMF but without HCl treatment. MS (LC/MS) m/z observed 568.92, expected 569.36 [M+H]. Compound was confirmed using LC/MS and moved to next step as it was.

Title compound 3-[(5-[(2S,4S)-4-cyclohexyl-2-[(2H-1,2,3,4-tetrazol-5-yl)methyl]carbamoyl]pyrrolidine-1-carbonyl]-1H-pyrrol-2-yl)(cyclopentyl)methyl]carbamoyl]propanoic acid (C9) was prepared from tert-butyl ((S)-5-((2S,4S)-2-(((2H-tetrazol-5-yl)methyl)carbamoyl)-4-cyclohexylpyrrolidine-1-carbonyl)-1H-pyrrol-2-yl)(cyclopentyl)methyl)carbamate and succinic anhydride using method E. An inseparable mixture of two diastereoisomers was obtained. ¹H NMR (400 MHz, DMSO-d₆) δ 0.87-1.01 (2H, m), 1.07-1.75 (18H, m), 1.94 (1H, m), 2.16 (1H, m), 2.25-2.45 (5H, m), 3.36 (1H, m), 3.97 (1H, m), 4.38 (1H, m), 4.48-4.57 (2H, m), 4.78 (1H, t, J=10 Hz), 6.02 (1H, m), 6.57 (1H, m), 8.12 (1H, d, J=9 Hz), 8.70 (1H, m), 11.1 (1H, s). MS (LC/MS) m/z observed 568.99, expected 569.32 [M+H].

Example D1

General Kinetic Enzyme Assay Protocol

A specific 2× assay buffer was prepared for the enzyme to be tested (see Table 2 for final 1× assay buffer compositions). If the assay buffer included DTT, it was added immediately prior to running the assay. A 2× enzyme mix was prepared (see Table 3 for enzyme assay conditions) at 80 uL per well. Compounds were screened at one or two appropriate concentrations (to determine the percent inhibition at those concentrations) and/or a full dose response curve (typically 8 points, to identify the IC₅₀) in duplicate, triplicate, or higher replicates as needed. An appropriate

control was also assessed in full dose response, in duplicate for each assay/plate. Background control wells consisted of 1× assay buffer, DMSO (5% v/v) and substrate. Positive

DTT, Glycerol and sucrose: Sigma-Aldrich, St. Louis, Mo., USA, NaCl and EDTA: Fisher Scientific, Pittsburgh, Pa., USA, CHAPS: Calbiochem, Billerica, Mass., USA.

TABLE 3

Enzyme assay conditions.						
Enzyme		Substrate		Assay		
		Conc.	Ex/Em λ*	Temp		
Name	Conc.	Name	(μM)	(nm)	(° C.)	Control Inhibitor
hGzmB	10 nM	Ac-IEPD-AMC	150	380/460	30	Ac-IEPD-CHO
Caspase-1	6.25 mU/μl	YVAD-AFC	25	400/505	37	Z-VAD-FMK
Caspase-3 and	6.25 mU/μl	Ac-DEVD-	20	380/460	37	Z-VAD-FMK
Caspase 7		AMC				
Caspase-4 and	3.125 mU/μl	Ac-WEHD-	100	400/505	37	Z-WEHD-FMK
Caspase-5		AFC				
Caspase-8	3.125 mU/μl	Ac-IEPD-AMC	75	380/460	30	Ac-IEPD-CHO
Caspase-9	3.125 mU/μl	LEHD-AFC	50	400/505	37	Q-LEHD-Oph
Caspase-10/a	6.25 mU/μl	Ac-IETD-AMC	100	400/505	30	Ac-AEVD-CHO

*Ex/Em λ is the excitation and emission wavelengths at which to measure fluorescence. Enzyme and substrate concentrations are the final concentrations in the well. Note that most protocols require preparing 2X enzyme and substrate mixes, as they are diluted 2-fold in the well.

control wells consisted of enzyme, DMSO (5% v/v) and substrate. Test compounds and control compounds were diluted in DMSO to 40× the final desired concentration. For example, a test compound may be tested in dose response, in serial, tripling dilution condition starting at 20 μM and ending at 9.1 nM (or any appropriate concentration range and dilution scheme). Control compounds were prepared similarly. Diluted compounds were prepared in a dilution plate and transferred to the reaction plate (96-well medium binding plate (Greiner Bio-One FLUOTRAC™)) to allow for the desired final concentrations when added to the enzyme with AB. After mixing, the reaction plate was placed on a shaker (at 300 RPM) for 5 min, followed by incubation (covered) on the bench, for 20 min. Plates were warmed to reaction temperature (see Table 3) for a total incubation time of 30 min. Plates so prepared were ready for addition of substrate and the subsequent reaction.

An appropriate substrate for each assay was prepared in advance at 2× the final desired concentration (see Table 2) in DMSO. The appropriate substrate mix was added to each appropriate well on the reaction plate, and the plate was read immediately in the TECAN plate reader (TECAN INFINITE® M1000 Pro), set to the correct wavelength as needed for each assay (see Table 3) using 25 cycles, kinetic interval of 1 min, number of reads per well of 20 with shaking set to 1 s, double orbital, 2 mm amplitude. For fluorescent assays the gain was set to optimal (50%).

TABLE 2

Assay Buffer Composition.	
Enzyme	Assay Buffer Composition
Caspase 1, 3, 4, 5, 7, 8*, 9 & 10/a (General caspase assay buffer)	50 mM HEPES pH 7.2 50 mM NaCl 0.1% (w/v) CHAPS 10 mM EDTA 5% (v/v) Glycerol 10 mM DTT
GzmB & Caspase 8	50 mM HEPES pH 7.5 10% (w/v) sucrose 0.2% (w/v) CHAPS 5 mM DTT

*Can also use GzmB assay buffer for the Caspase-8 assay; Assay buffer components were sourced as follows: HEPES,

Enzymes were sourced as follows: hGzmB, Froelich Lab, Northshore University Health Systems Research Institute, Evanston, Ill., USA; Caspases, Biovision Inc., Milpitas, Calif., USA. Substrates were sourced as follows: Ac-IEPD-AMC, California Peptide Research Inc., Napa, Calif., USA; YVAD-AFC, Biovision Inc., Milpitas, Calif., USA; Ac-DEVD-AMC, LEHD-AFC, AC-WEHD-AFC and Ac-IETD-AMC, Enzo Life Sciences Inc, Farmingdale, N.Y., USA. Control inhibitors were sourced as follows: Ac-IEPD-CHO, Ac-WEHD-FMK and Q-LEHD-Oph, Biovision Inc., Milpitas, Calif., USA; Z-VAD-FMK, R&D Systems, Minneapolis, Minn., USA; and Ac-AEVD-CHO, Enzo Life Sciences Inc, Farmingdale, N.Y., USA.

Example D2

Human Granzyme B Enzymatic Inhibition Assay

An in vitro fluorogenic detection assay for assessing the IC₅₀ and/or percent inhibition at a given concentration of inhibitors against human Granzyme B (hGzmB) enzyme was performed as described in Example D1. When appropriate, percent inhibition data was collected and fitted to generate IC₅₀ data using GraphPad Prism 5 (GraphPad Software, La Jolla Calif. USA, www.graphpad.com) and its non-linear regression analysis tools or other equivalent tools.

Select compounds of Examples C1-C9 exhibited inhibitory activity against hGzmB. Each of the compounds of the invention identified in Table 1 exhibited Granzyme B inhibitory activity.

In certain embodiments, select compounds exhibited IC₅₀<50,000 nM. In other embodiments, select compounds exhibited IC₅₀<10,000 nM. In further embodiments, select compounds exhibited IC₅₀<1,000 nM. In still further embodiments, select compounds exhibited IC₅₀<100 nM. In certain embodiments, select compounds exhibited IC₅₀ from 10 nM to 100 nM, preferably from 1 nM to 10 nM, more preferably from 0.1 nM to 1 nM, and even more preferably from 0.01 nM to 0.1 nM.

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Example D3

Human Caspase Enzymatic Inhibition Assay

In vitro fluorogenic detection assays for assessing the IC_{50} and/or percent inhibition at a given concentration of inhibitors, against a set of human Caspase enzymes, was performed as described in Example D1. Representative compounds of the invention do not significantly inhibit any caspase enzyme tested at a concentration of 50 μ M.

In certain embodiments, the compounds exhibited less than 50% inhibition at 50 μ M. In other embodiments, the compounds exhibited greater than 50% inhibition at 50 μ M, but less than 10% inhibition at 25 μ M.

Example D4

General Kinetic Enzyme Assay Protocol (384 Well)

A specific 2 \times assay buffer was prepared for the enzyme to be tested (see Table 4 for final 1 \times assay buffer compositions). If the assay buffer included DTT, it was added immediately prior to running the assay. A 2 \times enzyme mix was prepared (see Table 3 for enzyme assay conditions) at 26 μ L per well. Compounds were screened at one or two appropriate concentrations (to determine the percent inhibition at those concentrations) and/or a full dose response curve (typically 12 points, to identify the IC_{50}) in duplicate, triplicate, or higher replicates as needed. An appropriate control was also assessed in full dose response, in duplicate for each assay/plate. Background control wells consisted of 1 \times assay buffer and substrate. Positive control wells consisted of enzyme (no DMSO) and substrate. Test compounds and control compounds were diluted in 1 \times Assay Buffer to 15 \times the final desired concentration. For example, a test compound may be tested in dose response, in serial, tripling dilution condition starting at 20 μ M and ending at 0.1 nM (or any appropriate concentration range and dilution scheme). Control compounds were prepared similarly. Diluted compounds were prepared in a dilution plate and transferred to the reaction plate (384-well medium binding plate (Greiner Bio-One FLUOTRACTM)) to allow for the desired final concentrations when added to the enzyme with AB. After mixing, the reaction plate was placed on a shaker (at 300

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RPM) for 5 min, followed by incubation (covered) on the bench, for 20 min. Plates were warmed to reaction temperature (see Table 5) for 5 mins for a total incubation time of 30 min. Plates so prepared were ready for addition of substrate and the subsequent reaction.

An appropriate substrate for each assay was prepared in advance at 2 \times the final desired concentration (see Table 4) in assay buffer. 30 μ L of the appropriate substrate mix was added to each appropriate well on the reaction plate, and the plate was read immediately in the TECAN plate reader (TECAN INFINITE[®] M1000 Pro), set to the correct wavelength as needed for each assay (see Table 5) using 15 cycles, kinetic interval of 1 min, number of reads per well of 20 with shaking set to 1 s, double orbital, 2 mm amplitude. For fluorescent assays the gain was set to optimal (100% with gain regulation) for all assays except human GzmB which was set to 85 (with the z set at 23000 um).

TABLE 4

Assay Buffer Composition.	
Enzyme	Assay Buffer Composition
Caspase 1, 3, 4, 5, 7, 8*, 9 & 10/a (General caspase assay buffer)	50 mM HEPES pH 7.2 50 mM NaCl 0.1% (w/v) CHAPS 10 mM EDTA 5% (v/v) Glycerol 10 mM DTT
GzmB & Caspase 8	50 mM HEPES pH 7.5 0.2% (w/v) CHAPS 5 mM DTT
Cathepsin G	320 mM Tris-HCL pH 7.4 3.2 M NaCl

*Can also use GzmB assay buffer for the Caspase-8 assay; Assay buffer components were sourced as follows: HEPES, DTT, Glycerol and sucrose: Sigma-Aldrich, St. Louis, Mo., USA, NaCl and EDTA: Fisher Scientific, Pittsburgh, Pa., USA, CHAPS: Calbiochem, Billerica, Mass., USA.

TABLE 5

Enzyme assay conditions.						
Enzyme		Substrate		Assay		
		Conc.	Ex/Em λ^*	Temp		
Name	Conc.	Name	(μ M)	(nm)	($^{\circ}$ C.)	Control Inhibitor
hGzmB	10 nM	Ac-IEPD-AMC	50	380/460	30	V2248
Caspase-1	12.25 mU/ μ L	YVAD-AFC	5	400/505	37	Z-VAD-FMK
Caspase-3 and	0.8 mU/ μ L	Ac-DEVD-	40 &	380/460	37	Z-VAD-FMK
Caspase 7	& 1.5 mU/ μ L	AMC	5			
Caspase-4 and	3.125 mU/ μ L	Ac-WEHD-	40 &	400/505	37	Z-WEHD-FMK
Caspase-5	& 1.5 mU/ μ L	AFC	100			
Caspase-8	4 mU/ μ L	Ac-IEPD-AMC	80	380/460	30	Ac-IEPD-CHO
Caspase-9	2 mU/ μ L	LEHD-AFC	50	400/505	37	Q-LEHD-Oph
Caspase-10/a	3 mU/ μ L	Ac-IETD-AMC	10	400/505	37	Ac-AEVD-CHO
Cathepsin G	200 nM	Suc-AAPF-pNA	200 μ M	410	25	Cat G inhibitor
absorbance						
Human Neutrophil Elastase	0.125 μ g/mL	MeOSuc-AAPF-AFC	50	384/500	37	Sivelestat

*Ex/Em λ is the excitation and emission wavelengths at which to measure fluorescence. Enzyme and substrate concentrations are the final concentrations in the well. Note that most protocols require preparing 2X enzyme and substrate mixes, as they are diluted 2-fold in the well.

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Enzymes were sourced as follows: hGzmB, Froelich Lab, Northshore University Health Systems Research Institute, Evanston, Ill., USA; Caspases and Elastase, Biovision Inc., Milpitas, Calif., USA; Cathepsin G, Athens Research and Technologies, Athens, Ga., USA. Substrates were sourced as follows: Ac-IEPD-AMC, California Peptide Research Inc., Napa, Calif., USA; YVAD-AFC and MeOSuc-AAPF-AFC Biovision Inc., Milpitas, Calif., USA; LEHD-AFC and Suc-AAPF-pNA Millipore, Billerica Mass., USA. Ac-DEVD-AMC, AC-WEHD-AFC and Ac-IETD-AMC, Enzo Life Sciences Inc, Farmingdale, N.Y., USA. Control inhibitors were sourced as follows: Ac-IEPD-CHO, AC-WEHD-FMK, Q-LEHD-Oph and CatG inhibitor Biovision Inc., Milpitas, Calif., USA; Z-VAD-FMK, R&D Systems, Minneapolis, Minn., USA; and Ac-AEVD-CHO, Enzo Life Sciences Inc, Farmingdale, N.Y., USA. Sivelestat, Tocris Bioscience, Bristol, UK.

Example D5

Human Granzyme B Enzymatic Inhibition Assay

An in vitro fluorogenic detection assay for assessing the IC_{50} and/or percent inhibition at a given concentration of inhibitors against human Granzyme B (hGzmB) enzyme was performed as described in Example D4. When appropriate, percent inhibition data was collected and fitted to generate IC_{50} data using GraphPad Prism 5 (GraphPad Software, La Jolla Calif. USA, www.graphpad.com) and its non-linear regression analysis tools or other equivalent tools.

Select compounds of Examples C1-C9 exhibited inhibitory activity against hGzmB. Each of the compounds of the invention identified in Table 1 exhibited Granzyme B inhibitory activity.

In certain embodiments, select compounds exhibited $IC_{50} < 50,000$ nM. In other embodiments, select compounds exhibited $IC_{50} < 10,000$ nM. In further embodiments, select compounds exhibited $IC_{50} < 1,000$ nM. In still further embodiments, select compounds exhibited $IC_{50} < 100$ nM. In certain embodiments, select compounds exhibited IC_{50} from 10 nM to 100 nM, preferably from 1 nM to 10 nM, more preferably from 0.1 nM to 1 nM, and even more preferably from 0.01 nM to 0.1 nM.

Example D6

Human Caspase Enzymatic Inhibition Assay

In vitro fluorogenic detection assays for assessing the IC_{50} and/or percent inhibition at a given concentration of inhibitors, against a set of human Caspase enzymes, was performed as described in Example D4. Representative compounds of the invention do not significantly inhibit any caspase enzyme tested at a concentration of 50 μ M.

In certain embodiments, the compounds exhibited less than 50% inhibition at 50 μ M. In other embodiments, the compounds exhibited greater than 50% inhibition at 50 μ M, but less than 10% inhibition at 25 μ M.

Example D7

Inhibition of Cell Detachment by GzmB Assay

HDFa primary human fibroblasts were plated at 10 k/well in 200 μ l, approximately 20 hrs before treatment. The next day, controls and 100 nM GzmB (recombinant, human) plus

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or minus inhibitor treatments were prepared in serum-free media. GzmB and inhibitor were incubated for 20 minutes at RT before adding to cells. Before addition, media and serum was removed from the cells and the cells were washed with PBS (1 \times), using pipettes to prevent disturbing the cells. Treatment preparations (100 μ l) were added to the wells and incubated for 7 hours in a tissue culture incubator. After 7 hours, media and treatments were removed and the cells were washed with PBS (1 \times) to removed detached cells, using pipettes only. Phase pictures were taken then the PBS was removed and replaced with 100 μ l of serum-free media and 20 μ l of MTS and the cells were allowed to incubate for 3 hours in a cell culture incubator. After 3 hours the absorbance was read at 490 nm and a percent inhibition value for the treatments with inhibitors was determined from the control wells. The resulting data is shown in Table 6.

TABLE 6

Inhibition of Cell Detachment by GzmB Results.	
Compound	Percent Inhibition of cell detachment at 50 μ M
C3	91%

Example D8

Inhibition of Fibronectin Cleavage by GzmB

Black, 96 well high-binding assay plates (Griener Bio-one) were treated overnight at 4° C. with 40 μ l of 8 μ g/mL Hilyte Fluor 488 labeled Fibronectin (Cytoskeleton, Inc). After fibronectin coating, plates were washed 3 times in buffer (20 mM Tris-HCl, pH 7.4, 20 mM NaCl) then once with granzyme B assay buffer (50 mM HEPES, pH 7.5, 0.1% CHAPS). After washing, 50 μ l of granzyme B assay buffer was added to each fibronectin-coated well. In a separate non-binding 96 well assay plate 5 μ l of 20 \times inhibitor serial dilution stocks were added to 45 μ l of 2.22 \times GzmB mix to establish inhibition (enzyme/inhibitor mixes were all prepared in granzyme B assay buffer and were incubated first at room temperature for 20 minutes, then at 30° C. for another 10 minutes). After incubation, 50 μ l of this 2 \times enzyme/inhibitor mix was added to the corresponding coated well to initiate fibronectin cleavage (20 nM final granzyme B concentration, 8-point inhibitor dilution series starting at 50 μ M). The assay was conducted at 30° C. in the TECAN plate reader (TECAN INFINITE® M1000 Pro), which was programmed to monitor the kinetic fluorescence polarization signal (filter set Ex/Em 470 nm/527 nm) with readings taken every minute, for 1 hour. Proteolytic activity was evaluated as the rate of fluorescence enhancement in the parallel emission over the linear range of the reaction. % Inhibition values were calculated from assay controls and the resulting data is shown in Table 7.

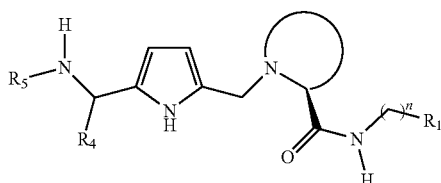
TABLE 7

Inhibition of Fibronectin Cleavage by GzmB Results.			
Percent Inhibition at Inhibitor Concentration			
Compound	50 μ M	5.56 μ M	0.62 μ M
C4	78%	56%	28%
C8	94%	83%	63%

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The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A compound having Formula (I):



Formula (I)

or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, wherein:

R₁ is a heteroaryl group selected from

- (a) 1,2,3-triazolyl, and
- (b) 1,2,3,4-tetrazolyl;

n is 1 or 2;

R₄ is selected from

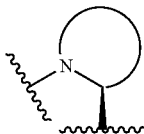
- (i) C₁-C₁₂ alkyl,
- (ii) C₁-C₆ heteroalkyl optionally substituted with C₁-C₆ alkyl,
- (iii) C₃-C₆ cycloalkyl,
- (iv) C₆-C₁₀ aryl,
- (v) heterocyclyl,
- (vi) C₃-C₁₀ heteroaryl,
- (vii) aralkyl, and
- (viii) heteroalkylaryl;

R₅ is —C(=O)—R₁₀,

wherein R₁₀ is selected from

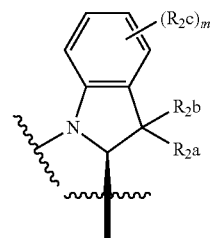
- (i) C₁-C₁₂ alkyl optionally substituted with C₆-C₁₀ aryl, C₁-C₁₀ heteroaryl, amino, or carboxylic acid,
- (ii) C₁-C₁₀ heteroalkyl optionally substituted with C₁-C₆ alkyl or carboxylic acid,
- (iii) C₃-C₆ cycloalkyl optionally substituted with C₁-C₆ alkyl, optionally substituted C₆-C₁₀ aryl, optionally substituted C₃-C₁₀ heteroaryl, amino, or carboxylic acid,
- (iv) C₆-C₁₀ aryl optionally substituted with C₁-C₆ alkyl, optionally substituted C₆-C₁₀ aryl, optionally substituted C₃-C₁₀ heteroaryl, amino, or carboxylic acid,
- (v) heterocyclyl,
- (vi) C₃-C₁₀ heteroaryl,
- (vii) aralkyl, and
- (viii) heteroalkylaryl;

wherein



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is selected from



wherein

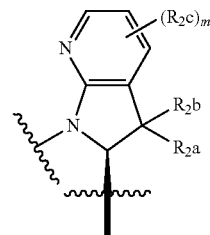
R_{2a} and R_{2b} are independently selected from hydrogen and C1-C6 alkyl; and

R_{2c} at each occurrence is independently selected from

- (a) hydrogen,
- (b) halogen,
- (c) C₁-C₆ alkyl,
- (d) —XR₁₁, wherein X is selected from O, C(=O), S, S=O, or S(=O)₂,
- (e) —C(=O)N(R₁₂)(R₁₃),
- (f) —N(R₁₁)(R₁₂)(R₁₃),
- (g) —N—C(=O)—R₁₁, and
- (h) —N—C(=O)O—R₁₁,

wherein R₁₁, R₁₂, and R₁₃ are independently selected from the group consisting of hydrogen, C₁-C₆ alkyl, C₁-C₆ heteroalkyl, C₂-C₆ alkenyl, C₆-C₁₀ aryl, aralkyl, and C₃-C₁₀ heteroaryl;

m is 1, 2, 3, or 4;



wherein

R_{2a} and R_{2b} are independently selected from hydrogen and C1-C6 alkyl; and

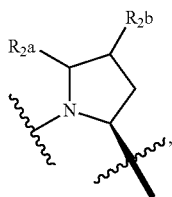
R_{2c} at each occurrence is independently selected from

- (a) hydrogen,
- (b) halogen,
- (c) C₁-C₆ alkyl,
- (d) —XR₁₁, wherein X is selected from O, C(=O), S, S=O, or S(=O)₂,
- (e) —C(=O)N(R₁₂)(R₁₃),
- (f) —N(R₁₁)(R₁₂)(R₁₃),
- (g) —N—C(=O)—R₁₁, and
- (h) —N—C(=O)O—R₁₁,

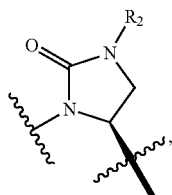
wherein R₁₁, R₁₂, and R₁₃ are independently selected from the group consisting of hydrogen, C₁-C₆ alkyl, C₁-C₆ heteroalkyl, C₂-C₆ alkenyl, C₆-C₁₀ aryl, aralkyl, and C₃-C₁₀ heteroaryl;

m is 1, 2, or 3;

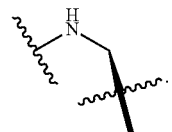
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wherein R_{2a} and R_{2b} are independently selected from hydrogen, C1-C6 alkyl, C3-C6 cycloalkyl, substituted and unsubstituted aryl, substituted and unsubstituted aralkyl, hydroxy, C1-C6 alkoxy, aryloxy, aralkoxy, alkylthio, arylthio, arylsulfonyl, arylsulfinyl, substituted and unsubstituted $-O(C=O)$ -aryl, substituted and unsubstituted $-O(C=O)$ -aralkyl, and substituted and unsubstituted $-O(C=O)$ -C1-C6 alkyl;

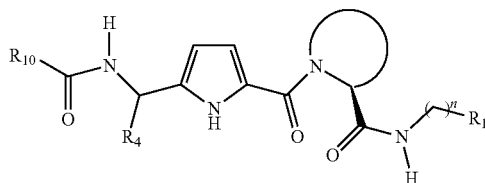


wherein R_2 is selected from hydrogen, C1-C6 alkyl, and C3-C6 cycloalkyl; and



2. A compound of claim 1 having Formula (II):

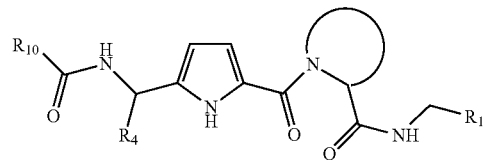
Formula (II)



or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof.

3. A compound of claim 1 having Formula (III):

Formula (III)



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or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof.

4. The compound of claim 1, or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, wherein:

5 R_{10} , when defined as C1-C12 alkyl substituted with a carboxylic acid or carboxylate group, is:

$-(CH_2)_n-CO_2H$, where n is 2, 3, 4, 5, or 6;

optionally wherein one or more single methylene carbons are substituted with a fluoro, hydroxy, amino, C1-C3 alkyl, or C6-C10 aryl group;

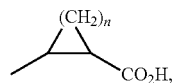
optionally wherein one or more single methylene carbons are substituted with two fluoro or C1-C3 alkyl groups;

optionally wherein one or more single methylene carbons are substituted with two alkyl groups that taken together with the carbon to which they are attached form a 3-, 4-, 5-, or 6-membered carbocyclic ring; and

optionally wherein adjacent carbon atoms from an unsaturated carbon-carbon bond or taken together form a benzene ring.

5 R_{10} , when defined as C3-C6 cycloalkyl substituted with a carboxylic acid or carboxylate group, is:

wherein R_{10} , when defined as C3-C6 cycloalkyl substituted with a carboxylic acid or carboxylate group, is:



wherein n is 1, 2, 3, or 4; and optionally, for $n=3$ or 4, wherein adjacent carbon atoms from an unsaturated carbon-carbon bond.

6. The compound of claim 5, or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, wherein:

35 R_4 is C1-C12 alkyl, C3-C6 cycloalkyl, C6-C10 aryl, C3-C10 heteroaryl, or heterocyclyl; and

R_{10} is C1-C12 alkyl optionally substituted with C6-C10 aryl, C1-C10 heteroaryl, amino, or carboxylic acid.

7. The compound of claim 5, or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, wherein:

R_1 is tetrazole or triazole;

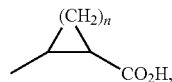
R_4 is C1-C8 alkyl or C3-C6 cycloalkyl; and

R_{10} is selected from:

45 (a) C1-C3 alkyl substituted with C6-C10 aryl (e.g., phenyl) or C1-C10 heteroaryl (e.g., triazolyl or tetrazolyl);

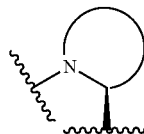
(b) $-(CH_2)_n-CO_2H$, where n is 2, 3, 4, 5, or 6;

(c)



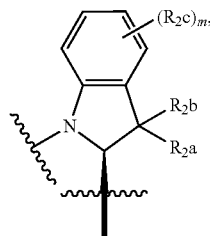
55 wherein n is 1, 2, 3, or 4.

8. The compound of claim 1, or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, wherein:



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is selected from



wherein

R_{2a} and R_{2b} are independently selected from hydrogen and C1-C6 alkyl; and

R_{2c} at each occurrence is independently selected from

(a) hydrogen,

(b) halogen,

(c) C₁-C₆ alkyl,

(d) —XR₁₁, wherein X is selected from O, C(=O), S, S=O, or S(=O)₂,

(e) —C(=O)N(R₁₂)(R₁₃),

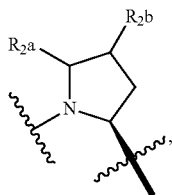
(f) —N(R₁₁)(R₁₂)(R₁₃),

(g) —N—C(=O)—R₁₁, and

(h) —N—C(=O)O—R₁₁,

wherein R₁₁, R₁₂, and R₁₃ are independently selected from the group consisting of hydrogen, C₁-C₆ alkyl, C₁-C₆ heteroalkyl, C₂-C₆ alkenyl, C₆-C₁₀ aryl, aralkyl, and C₃-C₁₀ heteroaryl;

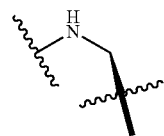
m is 1, 2, 3, or 4;



wherein R_{2a} and R_{2b} are independently selected from hydrogen, C1-C6 alkyl, C3-C6 cycloalkyl, substituted and unsubstituted aryl, substituted and unsubstituted aralkyl, hydroxy, C1-C6 alkoxy, aryloxy, aralkoxy, alkylthio, arylthio, arylsulfonyl, arylsulfinyl, substituted and unsubstituted

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—O(C=O)-aryl, substituted and unsubstituted —O(C=O)-aralkyl, and substituted and unsubstituted —O(C=O)—C1-C6 alkyl; and



9. A pharmaceutical composition, comprising a compound of claim 1, or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

10. A method for inhibiting Granzyme B in a subject, comprising administering an effective amount of a compound of claim 1, or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, to a subject in need thereof.

11. A method for treating dissection, aneurysm, or atherosclerosis, comprising administering a therapeutically effective amount of a compound of claim 1, or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, to a subject in need thereof.

12. A method for treating a wound, comprising administering a therapeutically effective amount of a compound of claim 1, or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, to a subject in need thereof.

13. The method of claim 10, wherein administering the compound, stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, comprises topical administration, oral administration, or administration by injection.

14. A method for treating cutaneous scleroderma, epidermolysis bullosa, radiation dermatitis, alopecia areata, or discoid lupus erythematosus, comprising administering a therapeutically effective amount of a compound of claim 1, or a stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, to a subject in need thereof.

15. The method of claim 14, wherein administering the compound, stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, comprises topical administration.

16. The method of claim 12, wherein administering the compound, stereoisomer, tautomer, or pharmaceutically acceptable salt thereof, comprises topical administration, oral administration, or administration by injection.

* * * * *